AN ABSTRACT OF THE THESIS OF

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Title: Test Development of Mathematics Subject Matter Knowledge Levels of Division of Rational Numbers for Thai Preservice Elementary Teachers

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The purpose of this study was to develop a valid and reliable, instrument for determining the mathematics subject matter knowledge of Thai preservice elementary teachers at eight (8) teachers' colleges in eight (8) provinces in northern Thailand. The focus of the content of interest was the operation of division of rational numbers in the context of an appropriate taxonomy of the cognitive domain categories suggested by Wilson (1971). The Delphi technique, item analysis, and "known group" techniques were utilized in the instrument development phases of the study. Hypotheses were tested to determine whether significant differences existed between colleges and between teachers with different backgrounds. The dependent variable was the mean test score for preservice teachers at eight Thai teachers' colleges. The study included the testing of significance for colleges, background, and whether there was significant interaction between colleges and teachers' backgrounds (liberal arts and science). The pilot instrument consisted of 52 items representing four
cognitive levels (computation, comprehension, application, and analysis). Based on an analysis of pilot test data, 10 items were eliminated. The final draft instrument consisted of 42 items and was administered to 272 preservice elementary teachers. When field test data were analyzed and compared to "known group" data, 10 items were found to be outside of the acceptability range for difficulty. Item difficulty was used for selecting items for inclusion in the final instrument to measure the operation of division of rational numbers with Thai college preservice elementary teachers. This step in the research served to reduce the number of test items to 32, which constituted the content for the final instrument.

The internal consistency reliability was .81 for the 42-item instrument. Content and construct validity were verified by various procedures.
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Levels of Division of Rational Numbers for
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Typed for researcher by Praphai Chalardkid
To my parents

Mr. Noo and Mrs. Sunee Chalardkid
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CHAPTER 1
INTRODUCTION

Recently, researchers have begun to pay attention to teacher subject matter knowledge. Teacher subject matter knowledge of mathematics had been neglected for several decades (Stein, Baxter, & Leinhardt, 1990). Subject matter knowledge is logically central to teaching mathematics but it is rarely the object of adequate consideration in preparing or certifying teachers (Buchman, 1984).

Since today's preservice elementary education teachers are tomorrow's teachers, the subject matter knowledge prospective teachers hold of fundamental mathematics operations is (or should be) a concern to teacher educators and researchers. However, few studies have explored the type and level of subject matter skill used and required by elementary education teachers (Leinhardt & Smith, 1985). Most instruments developed to measure elementary education teachers' mathematics subject matter knowledge have been qualitative. Such instruments were used by Ball (1990), who studied 19 teacher education students' knowledge of mathematics focus on division with fractions, division by zero, and division with algebra, and Riegel (1991), who interviewed 12 sixth grade students to assess students' misconceptions concerning rational numbers. Few quantitative instruments
have been developed for measuring mathematics subject matter knowledge of preservice elementary education teachers, especially in the area of division of rational numbers. One example is a multiple-choice test developed by the staff of the Project of Underprepared Mathematics Teacher Assessment to determine preservice teacher competencies in mathematics methods courses (Cangelosi, 1988). Another example is a multiple-choice test developed by Nowlin (1990) to assess the competence of preservice and inservice elementary teachers in the division of rational numbers.

Division is a key concept in the mathematics curriculum taught in elementary grades (Burns, 1991). Division is often perceived by teachers and students alike as the most difficult topic that confronts them in the classroom (Burton & Knifong, 1983). Several researchers have examined teacher knowledge of division (Greaber, Tirosh, & Glover, 1986, 1989; Tirosh & Greaber, 1988). Behr, Harel, Post, and Lesh (1990) demonstrated that primitive models of division influence the choice of operation of prospective elementary teachers. Ball (1990) found that the knowledge level of division among preservice teachers was fragmented. Freudenthal (1973) found that elementary teachers did not understand the differences between the two models of divisions nor even that an understanding of the division of rational numbers is necessary in the real world situations. It has been demonstrated that many teachers find rational number division to be difficult to understand and to teach (Ball, 1988; Leinhardt & Smith, 1985; Reys & Grouws, 1985; Wheeler, 1983).
Presumably, teachers able to demonstrate their knowledge of mathematics in communicable ways are able to teach mathematics effectively. If teachers have the ability to explain how to solve rational number division problems, they will be able to teach the other mathematics topics at the elementary level.

If we are to expect students to know and understand mathematics, then we should make sure that teachers know and understand mathematics and know how to teach the content. Whatever teachers know about mathematics topics will influence what they teach to their students (Vistro, 1991). In order to determine whether teachers’ subject matter knowledge of mathematics is adequate, a valid and reliable instrument is needed that measures the level of their mathematics subject matter knowledge, within the context of the cognitive domain.

Statement of the Problem

The assessment of subject matter knowledge of mathematics has taken on new importance in the preparation of teachers. Teacher competence has been judged through the use of assessment centers, formal evaluations of classroom instruction, and standardized examinations. Studies by cognitive psychologists have explored content knowledge of teachers to identify the effects of teachers’ subject matter knowledge on the transformation of textbook materials to the representations used in explanations of concepts and principles. The aim of this assessment has been to improve recognition of a teacher’s skill level so that preservice and inservice teacher training can be enhanced.
One important constraint in the improvement of content and methods courses for preservice and inservice elementary education teachers is the lack of specific instruments for evaluating teachers’ subject matter knowledge of mathematics, particularly division of rational numbers. Although division is a key topic in the elementary grades, it is the last of the four fundamental operations learned and is often perceived by teachers and students alike as being the most difficult (Burns, 1991; Burton & Knifong, 1983). Several studies have demonstrated that many teachers find rational number division to be difficult to understand and to teach (Ball, 1988; Leinhardt & Smith, 1985; Reys & Grouws, 1975; Wheeler, 1983).

Prior to this study, no instrument for the measurement of subject matter knowledge in mathematics had been developed for use among Thai preservice and inservice elementary education teachers. To borrow a western instrument and translate it into another language without consideration of cultural differences runs the risk of reflecting cultural bias and probably will result in a lack of cross-cultural validity (Brislin, 1986). Therefore, this study was intended to constitute a necessary first step that would lead to further research and ultimately culminate in the formulation of an instrument that could be used among preservice teachers and inservice elementary education teachers in throughout the nation of Thailand.

Purpose of the Study

The primary purpose of this study was to develop a valid and reliable instrument for determining the mathematics subject matter knowledge of Thai preservice elementary teachers in the operation of division with rational numbers, in
the context of an appropriate taxonomy of the cognitive domain categories suggested by Wilson (1971). Additionally, there was interest in testing for significant differences between different colleges and between teachers' backgrounds (i.e., liberal arts vs. science).

Division of rational numbers was selected as the topic of interest, and Nowlin's data test was used as a basis for developing an instrument to examine level of mathematics preparation and preparedness of preservice elementary education teachers in Thailand. The topic of division of rational numbers is the most difficult one (Leinhardt & Smith, 1985). In order to teach it effectively, teachers must have knowledge of more than mere content (Shulman, 1986) and they must be able to draw on such knowledge in providing explanations to students and in planning classroom activities.

The main objectives of this study were to:

1. Develop an instrument for measuring mathematics subject matter knowledge of the operations in division of rational numbers among Thai preservice elementary education teachers from eight teachers' colleges in northern Thailand.

2. Validate the instrument by administering it to representative samples of Thai preservice elementary education teachers.

3. Examine the response data collected from the administration of the instrument, and test for differences between teachers with liberal arts versus science backgrounds and between the eight teachers' colleges located in northern Thailand.
Assumptions

Assumptions for this study were:

1. Teachers must know mathematics content in order to teach mathematics.

2. Subject matter knowledge in the division of rational numbers is an good indicator of mathematical power, because this topic is difficult to understand and teach.

Limitations

The study was limited to seniors majoring in elementary education at eight teachers' colleges in northern Thailand. The test was not designed to predict course grades, but to measure mathematics subject matter knowledge relevant to the curriculum in Thai elementary and secondary schools. The findings were limited to the design and content of the instrument.

Definition of Terms

The following definitions are included to provide a clear understanding of the terms used in this study.

Cognitive domain: a category of the Taxonomy of Educational Objectives that deals with the recall or recognition of knowledge and the development of intellectual skills (Bloom, 1956; Wilson, 1971).
Known group: a sample of mathematics majors who served as a validation sample for the test.

Rational number: a number that can be represented by the quotient of two integers, \( a/b \), where the denominator, \( b \), is not zero. The common name for rational number is fraction (Underhill, 1972, p. 286).

Subject matter knowledge of mathematics: the knowledge of concepts, principles, facts, and characteristics of mathematics; understanding how knowledge is discovered, organized, tested; and knowledge of major issues in the field (McDiarmid & Ball, 1989).

Teachers’ colleges: Thai institutions offering associate and bachelor's degrees in education and other areas.

Thai novice elementary education teacher: teacher in first, second, or third year of teaching in elementary school.

Thai preservice elementary education teacher: a senior majoring in elementary education, enrolled at a teachers’ college in Thailand.
Summary

This chapter provided an overview of the study, including a statement of the problem. The purpose and objectives of the study were described for developing the instrument to measure mathematics subject matter knowledge of preservice elementary education teachers in Thailand. A definition of terms was included to facilitate a clear understanding of the terms being used in the study.
CHAPTER 2
REVIEW OF LITERATURE

The literature review was directed at four areas as follow:

1. Studies and other literature on the development of valid and reliable instruments, particularly for measuring preservice elementary education teachers' mathematics subject matter knowledge.

2. Studies on students' understanding of division and/or rational numbers.

3. Studies on teachers' mathematics subject matter knowledge, including preservice elementary education teachers' understanding of mathematics and the need for practical applications in teaching mathematics.

4. Studies in other areas employing similar design and/or statistical analyses as those of the then-proposed study.

Development of Valid and Reliable Instruments

The need to develop valid and reliable instruments to measure mathematics is the focus of the discussion in this section.

Following prescribed test development procedures is essential to the writing of valid and reliable items. Two typical examples of test development guidelines were provided by Krathwohl and Payne (1971) and Tinkelman (1971).

Krathwohl and Payne (1971) suggested the following sequence for test construction:
1. Specify the ultimate goals of the educational process.
2. Derive from the goals the portion of the system to be studied.
3. Specify this portion in terms of expected student behavior. If relevant, specify the acceptable level of successful learning.
4. Determine the relative emphasis or importance of various objectives, their content, and their behaviors.
5. Select or develop appropriate situations that will elicit the desired behavior in the appropriate context or environment.
6. Assemble a sample of such situations so that together they best represent the emphasis on content and behavior previously determined.
7. Provide for recording of responses in a form that will facilitate scoring, but does not change the nature of the behavior elicited, so that the scores are an accurate index of the behavior desired.
8. Establish scoring criteria and guides to provide objectives without bias.
9. Test the instrument in the preliminary form.
10. Revise the sample of situations on the basis of test response information.
11. Analyze the data for evidence of reliability, validity, and score distribution in accordance with purposes of use.
12. Develop test norms and a manual; reproduce and distribute the test.

Tinkelman (1971) suggested that, in defining the general purpose of a test, attention be given to the specific areas of achievement to be measured, the population to be measured, and the use of the scores. For the purpose of analyzing the items, he said it is valuable to look at the scores of different ability groups. He suggested the following sequence for test development:

1. Develop the test specifications.
2. Write the test items.
3. Pretest the items and analyze the item statistics.
4. Compile the preliminary test forms.
5. Test the preliminary test forms to verify time limits, difficulty and reliability.
6. Compile the final test forms for standardization purposes.
7. Administer the final test forms for standardization.
8. Prepare norms, a test manual, and supplementary test materials.
9. Print and publish.
The review of literature revealed several studies that had developed instruments for measuring competencies in mathematics. Ross and Maynes (1983) developed a test for assessing experimental problem solving skills. The domain to be evaluated was defined in terms of seven skills. The cognitive behaviors of novices and experts were contrasted and broken down into a series of levels, ranging from Level 2 to Level 7. A pool of multiple-choice items was developed for each skill. Each item pool was tested in three phases: (a) A test-retest reliability coefficient was based on Cronbach’s alpha (Cronbach, 1951). Both the test-retest coefficients and the internal consistency coefficients were too low for judgments about individuals, but were deemed appropriate to evaluate programs. (b) Content-related evidence of validity was determined from the agreement of science teachers and educators. (c) Construct-related evidence of validity was provided by comparing students who had recently received instruction on three of the skills with those who had not. Correlations for predictive reliability were lower than expected.

Cangelosi (1988) assessed interscorer reliability and score reliability for each subtest of a test developed by the staff of the Project of Underprepared Mathematics Teacher Assessment (PUMTA). He computed the standard error of measurement and determined the cutoff score for each subtest by focusing on competencies required in college methods courses for preservice mathematics teachers. Content was based on learning goals for grades 6 through 12 mandated by the State of Utah. Seven competencies were defined by sets of specific skills and abilities. Competencies were organized into a two-dimensional matrix, with the row specifying the content and the column specifying the cognitive behavioral construct.
of the first four elements of Bloom's taxonomy. Item pools for each cell of the matrix were developed by PUMTA staff. The items were refined by a panel of content specialists and then field tested by 90 mathematics teachers whose backgrounds ranged from "very unprepared" to "highly qualified." The validation study was conducted using a sample of teachers, of which 18 were "clearly underprepared," 18 were "clearly qualified," and 11 were "borderline in preparation."

Ibrahim (1990) constructed a paper-and-pencil instrument for measuring preservice elementary and secondary teachers' beliefs about mathematics. To validate the instrument, it was used in interviews with 302 volunteer preservice elementary and secondary teachers. The interview technique was used to generate the subjects' own beliefs and words about mathematics, establishing the content validity of the instrument. The researcher generated 470 beliefs about mathematics and reduced them to 60 statements, based on established criteria. Principal component factor analysis was used to explore the factor structure of the 60 items of the Mathematics Belief Instrument (MBI), establishing a multidimensional, rather than unidimensional, belief instrument. The 60 items clustered on five factors, which explained 31.4% of the total variance. The construct validity of the instrument was established through known-group validity and the convergent validity techniques. Five pairs of groups with different backgrounds in both mathematics and teaching methods were contrasted using t-tests. The results suggested that the background of preservice elementary and secondary teachers in both mathematics
and methods of teaching courses have contributed to the significant differences in
their beliefs about the nature of mathematics.

Nowlin (1990) developed a valid and reliable instrument to determine the
cognitive domain status of preservice and inservice elementary teachers in the
operation of division with rational numbers, in the context of Wilson’s taxonomy
(Wilson, 1971). The domain was defined with the cooperation of a panel of content
specialists recruited nationwide. The panel first established a list of tasks considered
representative of domains of interest. Objectives were selected to match the tasks,
and items were chosen or constructed to test the objectives. A panel of preservice
teachers rated each of the items for clarity.

To establish reliability and validity, Nowlin administered two 40-item forms
of the test to 79 students enrolled in mathematics education courses for elementary
teachers at Eastern Washington University, Gonzaga University, and Washington
State University during the Fall term of 1988. Using statistics generated by testing
these two forms, a third form with 64 items was constructed. The third form was
administered to 81 students enrolled in mathematics and mathematics education
courses at Eastern Washington and Gonzaga universities during the Fall term of
1989. Included in the sample were students from a foundations of mathematics
course that had a calculus prerequisite. Based upon the statistics accumulated with
the third form, a final, 48-item version of the instrument was assembled; the
statistics were reviewed to establish evidence of reliability and validity. The
reliability coefficients for the test results ranged from .872 to .886. The standard
error of measurement ranged from 2.778 to 2.946. Content-related evidence of
validity was established through the definition of the domain by content specialists and a table of specifications assigning the relative importance of each of the related objectives. Construct-related evidence of validity based upon the hierarchical structure of the domain was significant at $\alpha = 0.01$. A factor analysis yielding a single factor furnished further evidence of this structure. Construct-related evidence of validity based upon known groups was significant at $\alpha = .005$.

Studies on Division and/or Rational Numbers

This section explores students’ and teachers’ understanding of division and/or rational numbers. Several studies on rational numbers have examined students’ existing understanding of rational number concepts and operations.

Freudenthal (1973) believed that it was not important for elementary students to know the distinction between the two models of division. He said that, in metric, the division of rational numbers does not belong in the elementary curriculum. He believed fractions should be dealt with in algebra.

In regard to the present study, some of Freudenthal’s beliefs cannot be applied to the Thai elementary mathematics curriculum. In the Thai curriculum, both metric and English measure units are required to be taught, and the two models of division (long and short) are deemed important and necessary for students to learn.

Reys and Grouws (1975) interviewed children in the fourth, fifth, sixth, and eighth grades to determine their thoughts regarding division by zero. When confronted with a conflict between intuition and an inverse of multiplication
explanation, students would try to justify their intuition. For example, "8/0 = 0 because 8 x 0 = 0." The interviews showed the students had fundamental misconceptions concerning the number zero.

Behr, Wachsmuth, Post, and Lesh (1984) reported that students often are distracted by irrelevant features of rational number tasks when they are in the process of refining their understandings of a concept, and instruction often promotes rote and procedural, rather than rich, conceptual knowledge of rational numbers.

Sackur-Grisvard and Leonard (1985) noted the existence of several stages in students' learning of the concept of ordering decimal numbers. These researchers believed that the concept of stable intermediate organizations was developed by children in the process of learning the concept of ordering decimals.

Feinberg (1980) used measurement and the number line to illustrate the division of \( \frac{3}{4} \) by \( \frac{1}{4} \). She repeated the subtraction example which led to the development of the "common denominator" algorithm for the division of fractions. Previously, she had taught her students the following concepts of division of fractions: (a) Change unlike fractions to fractions with common denominators in adding and subtracting. (b) Any fraction can be represented in higher or lower terms to do multiplication or division involved in horizontal form. (c) Fractions and mixed numbers can be multiplied in horizontal form. (d) A whole number can be shown in fractional form (e.g., 3 = 3/1), and, conversely, a fraction with a denominator of 1 can be represented without the denominator (the identity property of division) (e.g., 3/1 = 3). From an understanding of (d), students can be led to understand that a compound fraction such as \( \frac{3}{4}/1 \) can be read as three-fourths
divided by one. Therefore, the representation \( \frac{3}{4}/1 = \frac{3}{4} \) can likewise be comprehended.

During the early development of fraction concepts, Feinberg gave each student in the class six strips of construction paper, all of the same length and width but in different colors. The strips were folded so that each strip represented a different set of fractions. The strips were used to compare fractions, find equivalent fractions, and add and subtract like and unlike fractions. The strips, together with the number line, were used as models in developing division of fractions.

Silvia (1983) suggested that graph paper be used to model the division of fractions. The basis of her model was measurement. She was able to relate division with fractions to division with whole numbers. The final abstraction of this method lead to the invert and multiply rule. She tried to avoid the answers of mixed number problems.

Although most rational number research has focused on school-aged children, there is an emerging body of research on elementary education teachers' understandings of rational numbers. Post, Harel, Behr, and Lesh (1988) found compound difficulties regarding classroom teachers' understandings of rational numbers. Not only did many teachers have difficulty in correctly answering conceptual and computational rational number questions, but many were unable to explain their solution processes in more than a procedural manner, even though they were asked to explain their solution to problems as if they were explaining them to a school-aged child.
Ball (1988) investigated the understanding of division with fractions among 318 preservice teachers, including elementary teachers and secondary teachers. Although most were able to "invert multiply" during the interviews, few were able to generate a mathematically appropriate representation of $\frac{1}{3}/\frac{1}{2}$ divided by $\frac{1}{2}$. Of the 35 preservice teachers interviewed on this question, only 4 were able to give an appropriate representation; 12 gave inappropriate representations; and 19 were unable to give any representation at all. Those who gave appropriate responses were all secondary mathematics majors. Few of the teacher candidates interpreted the division-with-fraction task as a case dealing with the concept of division. Instead, they focused on the fact that they were dealing with fractions. In contrast, the mathematics majors tended to see mathematics as a body of rules and facts and considered rules themselves to be adequate explanations. The secondary candidates had taken more mathematics courses than the elementary students and were more confident that they could remember rules and apply them correctly.

Ball (1990) studied 19 teacher education students' knowledge of mathematics and discussed an analytic framework for examining and appraising teachers' and prospective teachers' subject matter knowledge. The sample in the study consisted of 10 elementary education majors and 9 mathematics majors who were preparing to teach high school. The results focused on the concept of division examined across three mathematical contexts: division with fractions, division by zero, and division with algebra. Most of the teacher candidates produced correct answers, but only a few were able to give mathematical explanations for the underlying principles and meanings. The students' knowledge was also fragmented. The findings challenged
assumptions about the subject matter preparation of prospective elementary and secondary mathematics teachers.

Riegel (1991) interviewed 12 sixth-grade students to assess their modes of representation, successful strategies, and misconceptions concerning rational numbers. One classroom student was selected to be observed by videotape on nearly a daily basis for a period of 3 months. A post-interview and two teaching experiments were conducted with this student. Each experiment attempted to assist the student in self-correcting rational-number misconceptions; the second experiment also probed for the connections established between/among the various modes of rational numbers representations.

Data collected in Riegel’s study suggested that patterns existed in the responses to the initial interview. Among the patterns of responses was nearly a 75% correct response to the comparison of unit fractions. An area strategy using manipulative and/or pictures was implemented by the majority of these students. However, 75% could not locate the unit fractions on the number line, an unfamiliar task prior to the pre-interview.

For the case study student, the data suggested that the placement of fractions, including the fraction $\frac{1}{2}$, on the number line was successfully accomplished. At the conclusion of the first teaching experiment, the student was able to recall rational-number algorithms. By the second teaching experiment, the student was able to construct a successful solution for a part-to-part relationship, a concept that had been difficult for her ability to model solutions when she attempted to match procedures
to the model. However, at the same time, she was unable to recall the rational-number addition procedure.

Studies on rational number concepts have drawn similar conclusions. Most students (a) are developing only rote, procedural knowledge rather than rich understandings; (b) focus on syntactic rather than semantic rules; (c) prefer only one interpretation of rational numbers, the part-whole interpretation, often using a circular model; and (d) often have difficulty using models to illustrate operations or to connect operations on objects with symbolic algorithm.

Leinhardt and Smith (1985) explored the organization and content of subject matter knowledge of eight fourth-grade mathematics teachers, four experts, and four novices. Experts were selected because of the unusual and consistent growth score of their students in mathematics over a 5-year period. The novices were student teachers in their last year of a teacher training program and were considered to be the best student teachers by their supervisors. The teachers were given card sort tasks and interviewed on fraction topics from fourth-grade texts. The card sort task consisted of 40 mathematics problems and required a rationale for each sort. The teachers were interviewed on 12 fraction items.

The results reported for differences between novices and experts were consistent. Experts had more elaborate and deeper categories for problems; novices had more horizontal, separate-category systems. However, among the experts there were differences in levels of subject matter knowledge.
Schram, Wilcox, Laneir, and Lappan (1988) examined the piloting of a sequence of innovative mathematics courses for undergraduate education majors. The courses emphasized the conceptual foundations of mathematics and actively engaged prospective elementary teachers in making sense of mathematical situations. The main question the researchers sought to answer was: What is the nature and extent of changes in the knowledge about mathematics, mathematics learning, and mathematics teaching among students as a result of these courses? The results of the study suggested that change in two important areas occurred in student thinking about mathematics as a consequence of this intervention: (a) a change in students' conception of what mathematics is and (b) a change in their perception of what a mathematics class is like and in their knowledge of how mathematics is learned.

A study by Thipkong (1988) involved: (a) investigating preservice elementary teachers' interpretations and misconceptions of decimal notation involving subunits based on 10 and not based on 10, and with familiar and unfamiliar decimals; (b) describing the processes preservice elementary teachers use in solving decimal word problems involving multiplication and division with familiar and unfamiliar decimals on subunits based on 10 and not based on 10; and (c) the analysis of how preservice elementary teachers' interpretations and performances were affected by the misconceptions of decimal numbers. The subjects were 65 preservice elementary teachers enrolled in a methods course at the University of Georgia. The instrument was a two-part written test, with 26 "concepts" items in one part and 19 "word problems" in the other part. Nineteen of the subjects were interviewed.
The results of Thipkong's study showed that there was a positive relationship and a significant correlation between the concept scores and the problem solving scores at \( p < .01 \). In the "concepts" part, writing decimal numbers for the shaded areas were easier for preservice teachers to work with than plotting points on the number lines and shading the areas of the squares for the given decimals. In the "word problems" part, one-step word problems were easier for preservice teachers to work with than the subunits not based on 10 and were easier than the subunits based on 10. The money context was the easiest context comparing the time context and the measurement context. Decimals greater than 1 were easier than the decimals less than 1. The preservice elementary teachers' most common misconceptions in the "concepts" part were ignoring a zero value in the tenths place of a decimal number, and using numbers in the tenths place and the hundredths place of decimals as indicated by the next smallest unit in the subunits not based on 10. In the "word problems" part, the preservice elementary teachers interpreted decimals in the tenths and the hundredths places of units as indicating the next smallest unit in subunits of conversation; they also used wrong subunits in conversation.

Carpenter, Fennema, Peterson, Chiang, and Loef (1989) investigated teachers' use of knowledge from research on children's mathematical thinking and how their students' achievement is influenced. Twenty first-grade teachers were assigned randomly by school to the treatment group, which was given Cognitive Guide Instruction (CGI). These teachers participated in a 4-week summer workshop in which they studied a research-based analysis of children's development of
problem-solving skills in addition and subtraction. Another group of 20 first-grade teachers, who participated in two 2-hour workshops, focused on nonroutine problem solving. They were assigned randomly to a control group. The two groups were observed by trained observers during mathematics instruction throughout the following year. Near the end of the instructional year, teachers' knowledge of their students was measured by asking each teacher to predict how individual students in his or her class would solve specific problems and if correct answers would be obtained. Teachers' beliefs were measured using a 48-item questionnaire designed to assess their assumptions about the learning and teaching of addition and subtraction. Students in the 40 teachers' classes completed a standardized mathematics achievement pretests and tests.

The findings of the Carpenter et al. study showed that two major themes were reflected in the guiding principle of CGI. One was that instruction should develop understanding by stressing the relationship between skill and problem solving. The CGI classrooms were characterized by a greater emphasis on problem solving than would be found in traditional classrooms. Another major theme was that instruction should build on students' existing knowledge. It was implied that students solve different problems, so that teachers understanding students' knowledge and capabilities can adapt instruction appropriately.

Stein, Baxter, and Leinhardt (1990) investigated the relationship between teachers' knowledge of mathematics and the instructional practice of teacher and mathematics educators. Interviews and card sort tasks were designed for the study. The interview consisted of a series of open-ended questions regarding the topic of
functions and graphing and their instruction at the elementary level. The questions included a request for a definition of functions and comments regarding the importance of functions and graphing both within and outside of mathematics. Questions were included about how, when, and why functions and graphing should be included in the curriculum.

The card sort task was designed to ask each subject to categorize the cards based on a variety of criteria. The card sort task consisted of 20 cards, each of which had a mathematical relationship depicted on it. Subjects were asked to sort the cards into groups to give a description of each group. After one arrangement was completed, they were asked to categorize the cards again in a different way. Videotapes were then transcribed, capturing verbal exchanges between teacher and student actions. The analysis of the transcripts involved three phases: content analysis, instruction linked to teacher subject matter knowledge, and the ways in which subject matter knowledge may have influenced instruction. The findings suggested that limited subject matter knowledge led to the narrowing of instruction in three ways: (a) the lack of provision of groundwork for future learning in this area, (b) overemphasis of a limited truth, and (c) missed opportunities for fostering meaningful connections between key concepts and representations. The findings corroborated the conclusions of other studies and suggested that limited, poorly organized teacher knowledge often leads to instruction characterized by few conceptual connections, less powerful representations, and over-routinized student responses. The researchers pointed to the unique problems that arise when an unprepared teacher communicates ill-understood concepts to elementary students.
Ball and Wilson (1990) compared the mathematical understandings and pedagogical content knowledge of beginning teachers entering teaching through the Los Angeles Unified School District alternate route program with those entering from standard teacher education programs at three universities and colleges. The analysis challenged two common assumptions about becoming a secondary school mathematics teacher. The first assumption is that people who major in mathematics without an emphasis on education are both more capable and know more than their mathematics education peers. The second assumption is that professional knowledge and pedagogical content knowledge are best acquired through practical experience as a full-fledged teacher and that university-based teacher education can make few practical or significant contributions to what teachers need to know or be able to do. In the study, the overall proportions of novice teachers with conceptual understandings of elementary mathematics topics were discouraging. Neither the teacher education programs nor the alternate route had any consistently strong impact on novice teachers' ideas about the teachers' role or desirable practices in teaching mathematics. Many teachers in both groups were still unable to represent basic content in meaningful ways at the end of their programs. The supposed advantage of teaching experience in the case of the alternate route teachers did not emerge as a significant factor in the analysis.

Vistro (1991) investigated the nature of preservice elementary teachers' conceptual knowledge of perimeter, area, volume, and surface area; their procedural knowledge of the same concepts; and the linkages formed between these two kinds of knowledge. A 29-item written test, consisting of various problems on the four
measurement concepts, was administered to 65 preservice teachers. Eleven teachers were selected for the second interview, to complete additional measurement tasks. Findings revealed that the preservice elementary teachers (a) knew the basic concepts of perimeter and procedures for obtaining perimeter; (b) knew the basic concepts of area, but tended to rely on the formula, \( A = L \times W \), when obtaining it; (c) knew the basic concepts of volume, but were mostly familiar with the formula \( V = L \times W \times H \), for rectangular solids; and (d) hardly knew surface area and confused this concept with area. The data showed that preservice teachers held some misconceptions regarding measurement.

Schoenfeld (1989) explored aspects of the relationship between students' understandings about the nature of deductive proof in plane geometry and in other geometric endeavors. The subjects were 230 students enrolled in high school mathematics courses in the metropolitan area of Rochester, New York. A questionnaire containing 70 multiple-choice questions and 11 open-ended questions designed to give students the opportunity to present slightly more extended answers to issues of interest. The questionnaire dealt with the students' attributions of success or failure. The study reported the intersection of the cognitive and affective domains and examined the ways that people's conceptions of mathematics shape the way they engage in mathematical activities.

Studies Employing Similar Design and/or Statistical Analyses

Studies in other areas on development of instruments which were similar in procedure and/or analysis are discussed in the following section.
Rice, Gabel, and Brown (1991) developed an instrument to accomplish two things: (a) the identification of preservice elementary teachers' preknowledge relative to two concept areas, surface/volume and the states of matter, and (b) the characterization of these ideas as either "intuitive" or "school" knowledge. The first step in the development of the instrument was the collection of data relative to students' ideas about surface area/volume and state of matter. The researchers used students' comments and ideas reported by instructors in the science process skills course to develop test items. To provide a similar data bank for the development of the questions about the concepts of surface/volume, 25 students in the science process skills course were interviewed. From the taped interviews, ideas and explanations, both correct and incorrect, and "school" or "intuitive" knowledge were extracted. Information about students' ideas was again collected from several science process skills course instructors. Based upon these data, an 11-item multiple-choice test was developed. The questions format included a description of a situation, followed by a multiple-choice question about the situation and a list of between 8 and 20 possible explanations for the multiple-choice answer chosen. Care was taken to list both correct and incorrect explanations as well as explanations reflective of "intuitive" and "school" knowledge. The initial form of the test, which included 182 explanations for 11 items, was administered to four classes of a science skills course. Based on item analysis, the list of explanations was reduced, with items which were poor discriminators or appeared to be confusing being eliminated.

A panel of five experts were asked to review the instrument. Each of the individuals was either a science educator with chemistry teaching experience or an
experienced high school chemistry teacher. These experts were asked to take the
test and indicate for each explanation whether it was correct or incorrect relative to
the “correct” answer to the multiple-choice question and whether each explanation
represented “school” or “intuitive” knowledge. To qualify for inclusion in the test,
four of the five experts had to agree on both characterizations of an explanation.
Based on the judgments of the experts, non-qualifying explanations were eliminated.
The revised test was administered to four classes of the science process skills
course. Following item analysis, the number of explanations on the test was
reduced to a final total of 142. The reliability of the final form of the instrument
was determined the following semester by administering the test to four classes of
the science process skills course (Cronbach’s alpha ($\alpha$) = .94).

Giddings (1991) purposed to (a) determine the validity, reliability, and item
quality of a program-specific assessment instrument designed to measure student
mastery of core knowledge in the discipline of clothing and textiles; (b) evaluate
the effectiveness of the instrument in determining student outcomes from the
value-added perspective; and (c) determine whether performance on the instrument
and other measures of achievement was affected by student involvement
characteristics. The instrument contained 100 multiple-choice items relating to five
core courses. The instrument was divided into five subtests and was administered as
a pretest on the first day of the classes. The instrument in its full form was
administered to upperclass and underclass clothing and textiles majors and to
underclass clothing and textiles majors. Interviews were conducted with a subset of
students who had taken the subtests and the full exam and with faculty who taught
the course. The split-half and the KR-20 reliability estimates for internal consistency of the full test were greater than .70. The increase in student performance from pretest to test and the correlation between information obtained from the interviews with the results of the item analysis demonstrated the instrument's content validity. The significant difference between test scores for upperclass and underclass majors, and the correlation between course grade with the score on the instrument, demonstrated the construct validity of the instrument. The ability of the instrument to measure value-added knowledge was ascertained by the increase in student performance from pretest to test. The validity and reliability of the instrument were demonstrated and improvements in item quality and representation of course objectives on the core knowledge exam were made.

Martinez (1992) utilized a three-phase design to develop a valid and reliable instrument to measure foot care knowledge in elderly people with diabetes. Phase I focused on the survey of foot care content deemed important by a geographically random, stratified sample of 90 diabetes nurse educators. Data were used in Phase II to design a 25-item, multiple-choice foot care knowledge test corresponding to a third-grade reading level with face and content validity, as judged by diabetes experts. Pilot testing of the instrument was conducted in Phase III of the study, using 102 elderly people with diabetes and 103 without diabetes. Results yielded an index of internal consistency of .80 utilizing the KR-20 formula, with a modest test-retest correlation of .61 as derived from a subset of respondents with diabetes. Construct validity of the instrument was established via the principal component factor model as denoted by negligible to low partial corrections between test items; a
scree plot of eigenvalues; roots and proportion variance criteria; and measures of sampling adequacy. Further evidence of construct validity of the instrument was established employing criterion group analyses of foot care knowledge test scores. Subjects with diabetes and subjects with diabetes who received concentrated foot care education scored significantly higher on the test than did elderly subjects without diabetes. As a composite, the foot care knowledge test yielded an item difficulty index of 64%, with values ranging from 22% to 92%. All items exhibited positive discriminating power to distinguish high from low test scores with the test, as a whole, yielding an average discriminating power of .68, with values ranging from .57 to .82. Test item distracters (i.e., incorrect responses) were selected by a greater proportion of low versus high test scorers.

Summary

The review of literature described in this chapter focused on four areas of research: (a) development of valid and reliable instruments, particularly those for measuring elementary school preservice teachers' mathematics subject matter knowledge; (b) division and/or rational numbers; (c) mathematics subject matter knowledge; and (d) studies employing similar design and/or statistical analyses.
CHAPTER 3

METHODOLOGY

Development of the Instrument

The following procedural outline was used in this study:

1. **Develop item pool.**

Task items and behavioral objectives were pooled from the context of the Thai mathematics curriculum grades 1 through 12, and grouped into four sections accordingly to levels of Wilson's taxonomy (Appendix A). The sections were: computation, comprehension, application, and analysis. Five possible responses were provided for each multiple-choice test item. They consisted of one correct answer and four distracters. These, together with items from Nowlin's (1990) test, were translated into the Thai language to serve as a basis for instrument development in this study.

2. **Establish content validity of items.**

For the present study, the Delphi technique was used to establish content-based validity of the mathematics subject matter knowledge test. The Delphi technique is a non-empirical method for establishing content validity. It has been found to be appropriate for application in social science research (Courtney, 1991; Linstone & Turoff, 1975). The procedure is built on the premise of informed intuitive judgments and is intended to obtain professional opinion without bringing content (subject matter) experts together in a face-to-face meeting. Information from each of the panel members is assembled using successive questionnaires and
feedback, with each serial round being designed to produce closer and closer consensus among the judgments of 8 to 25 experts (Courtney, 1990).

The Delphi panel consisted of eight Thai mathematics education experts representing different institutions in Thailand. Each expert was experienced in research and/or in teaching mathematics in elementary schools, colleges or universities. Each had worked in her and his respective discipline for more than 10 years. The panel was composed of the following: two educators from Teacher Education Department, Ministry of Education, Thailand, who specialized in mathematics education, and research; a professor of Mathematics Education at Burapha University, Chonburi; the head of the Department of Elementary School Mathematics at the Institute for the Promotion of Teaching Science and Technology (IPST), Bangkok; three instructors in mathematics education from three teachers' colleges in Bangkok: namely, Suan Dusit, Suan Sunantha, and Dhonburi); and a teacher from Wat Parinayoke Elementary School, Bangkok. A detailed list of the panel members' qualifications is shown in Appendix B.

The Delphi procedure adopted for this study followed the steps outlined below:

1. The researcher sent an invitation letter, including an explanation of the purpose and potential contributions of this study, along with a summary of Wilson's taxonomy, to mathematics educators in Thailand. The intent of this step was to recruit eight mathematics educators to serve as Delphi panel members.

2. The researcher submitted a domain of the task items and behavioral objective items, and the translated version of the Nowlin's test to each of the eight
experts who agreed to serve on the Delphi panel. The process was as follows: In the first round, 16 task items (Appendix C), 16 behavioral objective items (Appendix D), and 48 translated test items from Nowlin’s test were submitted to each of the panel members. In this round, panel members were asked to rate each task, objective, and test item for appropriateness to the given level of the taxonomy, according to the procedure recommended by Martuza (1977). The scale of assigned ratings was as follows:

-1 = the item is judged not to be retained.
+1 = the item is judged to be retained.
0 = the item is assigned otherwise.

All task and test items and almost all (94%) of the objective items were retained, with 80% of the panel rating the items as appropriate (+1) (see Appendices E and F). It was suggested that objective item 3 be eliminated from Section 2 (comprehension) because of its similarity to objective item 2 (see Appendix F). It was also suggested that eight test items be added: two test items in Section 1 and six test items in Section 2. These suggestions, along with all retained objective and test items, were submitted to the entire panel in the second round.

In the second round, the Delphi panel members were asked to rate the appropriateness of each of the test and objective items. The 15 objective items and 48 test items previously retained were again rated appropriate (+1) by 80% of the panel members (see Appendix F). Objective item 3 in Section 2 (comprehension) was eliminated, and four of the eight additional test items were eliminated. The 52-test items retained were readied for use in the next phase of evaluation.
3. Screen the test items for clarity.

Before the pilot test was conducted, 34 seniors, majoring in elementary education at Pranakorn Teachers’ College, in Bangkok, rated each item with respect to clarity, on a 6-point scale. The rating scale used for this step consisted of the following:

- 0 = Very Difficult
- 1 = Difficult
- 2 = Somewhat Difficult
- 3 = Somewhat Clear
- 4 = Clear
- 5 = Very Clear

The 52-item instrument consisted of four sections. The computation section included 14 items; the comprehension section, 12; the application section, 12; and the analysis section, 12. The criteria for retaining items were as follows. For the computation items, if 30% or more of the students gave a rating of less than 4 ("Clear"), the item was removed from the pool. For other levels, if 30% or more of the students gave an item a rating of less than 3 ("Somewhat Clear"), the item was removed from the pool (Nowlin, 1990). However, all items were retained when this stage was completed (see Appendices G, H, I, and J). Thus, an item pool of 52 test items was finalized for the pilot study.

4. Establish content-related validity of items.

Courtney (1991) suggested that a general method of field testing be used to determine content-related evidence of validity after the item pool is finalized. He
stated that the pilot sample should consist of not fewer than 30 subjects who are randomly selected.

An instrument consisting of the 52 test items retained after content evaluation by the Delphi panel members and screening for clarity by preservice elementary teachers was used in the pilot test. The pilot test was conducted using 30 preservice elementary teachers who were seniors majoring in elementary education at Petburi Teachers’ College, in Petburi Province.

Response data derived from the pilot test were analyzed by using item analysis and a difficulty index (Gronlund, 1985; Kubiszyn & Borich, 1993; Wiersma & Jurs, 1990). The point-biserial correlation coefficient “r_{pbis)” (Courtney, 1988; Henrysson, 1971) was used to compute the reliability for each item. The Kuder-Richardson formula 20 (KR-20) was used to determine the internal consistency reliability for the pilot test (52-item) instrument (Wiersma & Jurs, 1990).

The item discrimination index treats the dichotomized item variable as a true dichotomy (right or wrong) (Henrysson, 1971). In situations where test items do not meet the standards of reliability, the reliability can be increased by adding items to and lengthening the test (Gronlund, 1985) and/or by choosing items which are easier and have a relatively high point-biserial correlation coefficient “r_{pbis)” (Henrysson, 1971). As a consequence of item analysis, some items were reworded to improve the difficulty index “p”. An instrument consisting of 42 test items was drafted, and it was considered to be the final draft instrument, assuming the reliability was satisfactory and the evidence of construct and content validity was adequate for
inferring validity. The final draft instrument was reviewed by the researcher's graduate committee members at Oregon State University (Appendix K). No changes were suggested following this review.

5. Field test instrument.

Procedural steps used to facilitate data collection from the target population were as follows:

a. The Thai Teacher Education Department, Ministry of Education, Thailand was contacted to obtain permission to conduct the study.

b. The rector of each teachers' college selected for inclusion in the study was contacted to obtain permission to gather data from his or her college. If permission was granted, the college was to provide a list of randomly selected instructors. (See Sample Selection section for details regarding the study population.)

c. The researcher contacted the identified instructors to arrange a convenient date and time to administer the test.

d. The tests were administered to the sampled groups and known group during September 1993.

6. Perform data analyses.

The field test responses were examined for completeness and clarity, and then coded so that computerized statistical analyses could be performed. The SPSS-PC package was utilized. The data processing steps for the study were considered complete following this phase.
7. Examine results of data analyses, test hypotheses and, based on the findings, revise and document final instrument.

Sample Selection

The study utilized a cluster sampling plan to select eight out of fourteen classes, generating a sample of 272 subjects from a target population of 424. All respondents were seniors majoring in elementary education at eight teachers' colleges in northern Thailand: namely, Chiangrai, Chiangmai, Lampang, Uttaradit, Kampangpet, Nakornsawan, Piboonsongkram, and Petchaboon (see Appendix Y for map of region in which data were collected).

Table 3.1 illustrates the sample distribution according to college and academic background. The cell size met Cohen’s (1969) criteria for significance for testing, where the power of the test was set at .70 and effect size was set at .30.

<table>
<thead>
<tr>
<th>College</th>
<th>Number of Students</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Liberal Arts</td>
<td>Science</td>
</tr>
<tr>
<td>1. Chiangrai</td>
<td>11</td>
<td>24</td>
</tr>
<tr>
<td>2. Chiangmai</td>
<td>28</td>
<td>19</td>
</tr>
<tr>
<td>3. Lampang</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>4. Uttaradit</td>
<td>22</td>
<td>18</td>
</tr>
<tr>
<td>5. Kampangpet</td>
<td>16</td>
<td>28</td>
</tr>
<tr>
<td>6. Nakornsawan</td>
<td>19</td>
<td>14</td>
</tr>
<tr>
<td>7. Piboonsongkram</td>
<td>9</td>
<td>21</td>
</tr>
<tr>
<td>8. Petchaboon</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>28</strong></td>
<td><strong>144</strong></td>
</tr>
</tbody>
</table>
Hypotheses Testing

The hypotheses of the study were tested utilizing a fixed two-way ANOVA design. The mathematical model for the two-way arrangement was:

\[ Y_{ijk} = \mu + a_i + b_j + ab_{ij} + e_{ijk} \]

where:
- \( \mu \) is a fixed unknown constant,
- \( a_i \) is the effect related to background,
- \( b_j \) is the effect related to college,
- \( ab_{ij} \) is the interaction effect, and
- \( e_{ijk} \) is the residual (error).

The following hypotheses were tested:

**H_1.** There is no college effect.

**H_1:** \( \mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5 = \mu_6 = \mu_7 = \mu_8 \)

**H_2.** There is no student background effect.

**H_2:** \( \mu_A = \mu_S \)

**H_3.** There is no interaction effect between colleges and students backgrounds.

For hypotheses testing, the significance level was set at \( \alpha = .05 \).

Summary

This chapter described the procedures and methods utilized in the study. Of primary importance was the gathering of evidence to support the validity and reliability of the instrument.
A test is valid if it measures what it says it measures (Kubiszyn & Borich, 1993). Validity refers to the appropriateness of the interpretation of the results obtained by the administration of an evaluation instrument to a given group of subjects, and not to the instrument in use. Validity is influenced by uniform aspects of measurement, including test format, the conditions of administration, and the language level in use.

Kubiszyn and Borich (1993) summarized construct-related evidence of validity as a type which “is determined by finding whether test results correspond with scores on other variables as predicted by some rationale or theory.” Construct-related evidence of validity involves the test’s ability to measure the individual’s actual difference from others. Construct-related evidence of validity is important in the validation of the purported characteristics for a newly developed instrument.

Construct validity of the instrument developed in this study was supported using Pearson correlation procedures, using pilot test data from a teachers’ college in Petburi Province, Thailand, and field test data taken from the eight teachers’ colleges in northern Thailand.

Content-related evidence of validity for the instrument developed for this study was established by: (a) creating an item pool, (b) obtaining the judgments of a Delphi panel of content specialists and mathematics educators re item appropriateness, (c) item analysis, and (d) determination of internal consistency reliability of the instrument. Factor analysis was used to establish the dimensional aspects of the instrument.
CHAPTER 4
RESULTS OF THE STUDY

Pilot Test

Reliability of the Instrument

The Kuder-Richardson 20 formula was used to calculate the internal consistency reliability of the 52-item instrument utilized in the pilot test. The resulting correlation was +.86, which was considered as being moderately high (Courtney, 1990). This result indicated acceptable reliability for the instrument.

The reliability of individual items was determined using the point-biserial correlation coefficient. Individual correlations were considered in the pilot testing as part of the item analysis procedure for purposes of improving for the instrument.

Analysis of point-biserial correlations was made to support the assessment of the instrument in the pilot test. This type of analysis is used to determine whether a test measured a common attribute and, in essence, content. The correlation of each respondent’s test score with his or her total test score is common practice for selecting items which are homogeneous. Items with moderately high correlations are usually retained for inclusion in final instruments. Positive point-biserial correlation for each item is necessary for judging the test item to be retained. There are instances when high point-biserial correlations exist and the pool of items are heterogeneous (Green, Lissitz, & Mulaiks, 1977).

Scale means, variances, alpha coefficients (if items are deleted), and corrected point-biserial correlations were calculated for each of the 52 items in the
pilot test instrument. The results reported in Table 4.1 indicated that there was need for further refinement in the instrument and that some items should be reconsidered for deletion from the test if it was to be considered to have content validity. The alpha levels indicated the reliabilities for the items and were considered adequate for purposes of testing.

Table 4.1. Point-Biserial Correlations for Pilot Test Items

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Mean (if item deleted)</th>
<th>Variance (if item deleted)</th>
<th>Point-Biserial Correlation (corrected)</th>
<th>Alpha (if item deleted)</th>
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Table 4.1 continued

<table>
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<tr>
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<th>Variance (if item deleted)</th>
<th>Point-Biserial Correlation (corrected)</th>
<th>Alpha (if item deleted)</th>
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<td>44</td>
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<td>59.6103</td>
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<td>.8597</td>
</tr>
</tbody>
</table>
Item Difficulty

Item difficulty is a measure of the easiness of an item in terms of percentage of respondents who correctly answered the item. It is reported as an index which ranges from zero (every respondent got the item incorrect) to 1.00 (everyone answered the item correctly). Both of these extreme values indicate items which do not discriminate between respondents, based on ability or knowledge. While extreme-valued items do not in themselves harm the test as a whole, they do take up space that could be given to items which are more discriminating. For an item having four or more response choices, the standard for judging whether or not an item should be retained is that the difficulty index should be between .35 and .85 (Beekman, 1977). Hills (1981) stated that with five alternatives (responses), the optimum difficult level for a test should equal to about 69% getting the item correct.

Difficulty indexes for the pilot test data are shown in Table 4.2. These data indicate that pilot test items 20, 22, 25, 29, 30, 36, 39, 41, 43, 44, 46, 47, and 50 did not meet the criteria of being above .35. Pilot test items 1, 2, 4, 8, 12, and 19 had difficulty indexes above .85 and were eliminated from the test.

Field Test

Reliability of the Instrument

The Kuder-Richardson 20 formula was used to calculate the internal consistency reliability of the 42-item field test instrument data obtained reliability coefficient for the field test data was +.81, which was considered as being
Table 4.2. Difficulty Indexes for Pilot Test Items

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Difficulty Index</th>
<th>Item Number</th>
<th>Difficulty Index</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td>.93</td>
<td>27</td>
<td>.70</td>
</tr>
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<td>2</td>
<td>.90</td>
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<td>.20</td>
</tr>
<tr>
<td>4</td>
<td>.98</td>
<td>30</td>
<td>.07</td>
</tr>
<tr>
<td>5</td>
<td>.67</td>
<td>31</td>
<td>.60</td>
</tr>
<tr>
<td>6</td>
<td>.77</td>
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<td>.50</td>
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<td>.77</td>
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<td>.60</td>
</tr>
<tr>
<td>26</td>
<td>.77</td>
<td>52</td>
<td>.63</td>
</tr>
</tbody>
</table>
moderately high (Courtney, 1990). This result indicated acceptable reliability for the field test instrument.

**Point-Biserial Correlations**

An analysis of interrelationships was made for the field test data using point-biserial correlation. This analysis of the field test data was completed for each of the four parts of the test (computation, comprehension, application, and analysis). Scale means, variances, alpha (reliability) coefficients (if items are deleted), and corrected point-biserial correlations for each of the four subsections of the instrument are shown in Appendices L through O. The coefficients were, in general, smaller than those for the pilot test data, primarily because the field test instrument was a shorter version of the pilot test instrument. Shorter tests tend to have lower reliability coefficients than do longer tests. The KR-20 reliability correlations for each of the four subsections of the field test instrument are shown in Table 4.3.

The reliability coefficients appeared to be adequate for computation, comprehension, and application sections of the instrument (.74, .72, and .72, respectively). However, the reliability coefficient for the analysis section (.48) was below that which is recommended for test development. The small number of items being considered may have resulted in the reliability coefficients for the sections being lower than for the entire 42-item instrument. A second consideration regarding the lower coefficient for the analysis subsection was that the items were more difficult for that section of the test than for other sections (item difficulty is
Table 4.3. Reliability Coefficients for Subsections of the Field Test Instrument

<table>
<thead>
<tr>
<th>Subsection</th>
<th>Number of Item</th>
<th>Reliability Coefficient (KR-20)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>10</td>
<td>.74</td>
</tr>
<tr>
<td>Comprehension</td>
<td>10</td>
<td>.72</td>
</tr>
<tr>
<td>Application</td>
<td>12</td>
<td>.72</td>
</tr>
<tr>
<td>Analysis</td>
<td>10</td>
<td>.48</td>
</tr>
</tbody>
</table>

Note. N = 272.

discussed in detail later). It is supported by the theory that there is a definite qualitative step between the lowest and all subsequent levels, and it is also evidence that the instrument measures this step.

Intercorrelations of the four subsections of the field test reflected coefficients similar to the reliability coefficients shown in Table 4.3. The intercorrelations are presented in Appendix P. The reliability of +.81, reported earlier, for internal consistency reliability of the entire field test instrument is a more realistic indicator than the reliability coefficients for the four sections. The reliability for the field test instrument was considered to be adequate for data gathering.

Item Difficulty

The field test data were analyzed for item difficulty using the same procedure as was utilized with the pilot test data. For an item having four or more response choices, the standard for judging whether the item should be retained following the
field test was that the item's difficulty index should be between .35 and .85. This standard is the same one used in assessing the items in the pilot test instrument. Items 11, 18, 22, 28, 33, 34, 36, and 38 had difficulty indexes below .35. Item number 31 was marginal with a difficulty index of .35, and 2, 3, and 6 had difficulty indexes above .85. These items were considered for rejection as the final draft instrument was prepared. Difficulty indexes for the field test data are shown in Table 4.4.

**Factor Analysis of Field Test Data**

An instrument which lacks unidimensionality is measuring more than one factor, and this is a threat to content validity. Factor analysis procedures were employed in order to evaluate the dimensional quality of the instrument. Eigenvalues were inspected for purposes of determining the number of factors to be computed for the final test data. An eigenvalue of 1.000 or higher was considered as indicative of the presence of a subfactor. Factor rotation methods and “scree” test procedures (Cattell, 1966) were used for establishing the numbers of factors to be generated for the data. Factor analysis was utilized to confirm the general construct composition (Lindeman, 1967) of the instrument, rather than as a method for selecting items.

Four separate factor analyses were computed, one for each of the sections (computation, comprehension, application, and analysis). The results of these analyses are shown in Appendices Q through T. The factor analysis result showed
that multidimensional qualities were present in each of the four levels the instrument.

Table 4.4. Difficulty Indexes for Field Test Items

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Difficulty Index</th>
<th>Item Number</th>
<th>Difficulty Index</th>
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</table>
Results of Hypotheses Testing

The hypotheses of interest in the study included the testing of effects associated with background of participants (liberal arts or sciences) and colleges (eight teachers' colleges located in northern Thailand) comprising the main effects. Thus, two levels of background and eight colleges were represented in the two-way fixed model analysis of variance design for the hypotheses testing. The analysis produced the results shown in Table 4.5.

Table 4.5. Results of Two-Way Analysis of Variance for Backgrounds and Colleges

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<th>p</th>
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<td>15.238</td>
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</tr>
<tr>
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<td>9.818</td>
<td>&gt; .01</td>
</tr>
<tr>
<td>Interaction</td>
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<td>14.174</td>
<td>3.827</td>
<td>&gt; .01</td>
</tr>
</tbody>
</table>

Note. N = 272.

Differences were found for the main effects and for the interaction source of variation. Further analyses using Tukey's test were required for determining where differences existed between levels of the college variable.

An inspection of the means was necessary to determine whether differences existed for background. The overall mean for students with a science background was 25.67. The mean for students with a liberal arts background was 18.16. Those with a science background had significantly higher scores than did those with a liberal arts background (Figure 4.1).
Figure 4.1. Means for students with science and liberal arts backgrounds.

Means, standard deviations, and standard errors for each of the colleges were used in making multiple comparisons. These statistics are displayed in Table 4.6.
Table 4.6. Means, Standard Deviations, and Standard Errors for Colleges

<table>
<thead>
<tr>
<th>College</th>
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<th>Standard Deviation</th>
<th>Standard Error</th>
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</thead>
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<td>1.39</td>
</tr>
<tr>
<td>2</td>
<td>42</td>
<td>26.07</td>
<td>6.83</td>
<td>1.05</td>
</tr>
<tr>
<td>3</td>
<td>17</td>
<td>19.00</td>
<td>3.35</td>
<td>0.81</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>22.28</td>
<td>6.71</td>
<td>1.06</td>
</tr>
<tr>
<td>5</td>
<td>44</td>
<td>20.84</td>
<td>8.27</td>
<td>1.25</td>
</tr>
<tr>
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<td>33</td>
<td>18.82</td>
<td>7.15</td>
<td>1.25</td>
</tr>
<tr>
<td>7</td>
<td>30</td>
<td>24.13</td>
<td>8.39</td>
<td>1.53</td>
</tr>
<tr>
<td>8</td>
<td>31</td>
<td>17.19</td>
<td>4.73</td>
<td>0.85</td>
</tr>
</tbody>
</table>

The determination of differences in means between levels for colleges required that a multiple comparisons analysis be conducted. Tukey's HSD procedure, a pairwise comparison test, was selected for this analysis because it retains an error rate of only 5% when the .05 level is being utilized (Cochran & Cox, 1957: Courtney, 1984). When assumptions are made regarding the committing of Type I errors, the Tukey’s test is considered to be more appropriate than other multiple comparison methods. Cochran’s C test showed that the variances were equal for college data. This criterion is necessary for using Tukey’s HSD test. The results of the multiple comparison analysis, when all 42 item scores were averaged, are summarized in Figure 4.2. It should be noted that the college means marked by an asterisk (*) were determined to be significantly different according to Tukey’s HSD test results.
The mean for College 7 was found to be significantly larger than the mean for College 8. Colleges 2 and 1 had mean scores which were significantly larger than the mean scores for Colleges 8, 6, 3, and 5. The other means were not significantly different.

When college mean scores for each of the four sections of the instrument (cognitive levels for computation, comprehension, application, and analysis) were subjected to the Tukey’s test, the means for Colleges 1, 7, and 2 were found to be significantly higher than the others for nearly all of the comparisons. Figure 4.3 graphically displays means comparison.
Additional multiple comparison testing was conducted, including data for mathematics majors from a ninth college. This group of respondents was keyed as College 9 and treated as a "known group" for purposes of comparing the scores in math of elementary education majors from the eight colleges with the scores of mathematics majors. Means, standard deviations, and standard errors for College 9 are reported in Table 4.7.
Table 4.7. Mean, Standard Deviation, and Standard Error for College 9

<table>
<thead>
<tr>
<th>College</th>
<th>N</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>30</td>
<td>33.83</td>
<td>6.64</td>
<td>1.21</td>
</tr>
</tbody>
</table>

When the Tukey’s test was utilized to contrast these data with the data for the other eight colleges, the test score average (33.83) for College 9 was found to be significantly larger than those for the other colleges. This finding indicated that the test instrument was appropriate for the testing of mathematics content as perceived by math majors and implies that the instrument has validity for that purpose (see Figure 4.4 for mean differences).

Item difficulty was also considered for the College 9 sample. As shown in Table 4.8, the “known group” response was inadequate for only items 33 and 36; difficulty indexes were .30 and .07, respectively. The two items met Beekman’s criterion for acceptability when field test data for the preservice teachers were analyzed; they had difficulty indexes above .35 and below .85. The items appeared to be poorly written or have elements that were confusing to the respondents. Figure 4.5 shows difficulty index differences between the “known group” and the sampled group.
Figure 4.4. Means for sampled group and “known group.”
Table 4.8. Item Difficulty Indexes for College 9 Field Test Data

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Difficulty Index</th>
<th>Item Number</th>
<th>Difficulty Index</th>
</tr>
</thead>
<tbody>
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<td>.73</td>
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<td>21</td>
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</table>
Figure 4.5. Difficulty index differences between “known group” and sampled group.
Summary

This chapter reported the analyses of pilot and field test data. The analytical procedures used were factor analysis, analysis of variance, multiple comparisons, and evaluation of "known group" sample results. Following the analysis of the pilot test data, the number of test items was reduced from 52 to 42 for the field test instrument.
CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

Summary of the Study

The central purpose of this study was to develop a valid and reliable instrument for determining the mathematics subject matter knowledge of Thai preservice teachers at eight teachers' colleges in northern Thailand. The focus of the content of interest was the operation of division of rational numbers, in the context of an appropriate taxonomy of the cognitive domain (Wilson, 1971). Item analysis and "known group" techniques were used. In addition, statistical analyses were performed to determine whether significant differences in mean scores existed between colleges and/or between the academic backgrounds of the preservice elementary teachers in the eight teachers' colleges in northern Thailand participating in the study. A sample of mathematics majors in a ninth college served as the "known group" for comparison purposes.

Pilot and field testing were used in the validation phase of the instrument development process. The obtained reliability coefficients were calculated by the Kuder-Richardson 20 method. The consistency measure for the pilot test instrument was +.86 and for the field test instrument was +.81.

The initial screening procedures (Delphi technique) resulted in a 52-item instrument, which was subsequently subjected to a pilot test. Based on the analyses of the pilot test data, the number of acceptable test items was reduced to 42. These test items were then used in a field test administered to randomly selected preservice
elementary teachers at eight teachers’ colleges in northern Thailand. When field test data were evaluated in terms of item acceptability, ten items were found to out of the acceptable range for difficulty and another item was marginal. Ultimately, the final instrument was reduced to 32 items. The English version of the final instrument is shown in Appendix U, and the Thai version is shown in Appendix V.

Conclusions

1. The findings supported the theoretical basis for the developed instrument. That is, there is a qualitative step between the lowest levels (computation) and all subsequent levels (comprehension, application, and analysis, respectively), and this step can be measured. The developed instrument measured the Thai preservice elementary teachers’ mathematics subject matter knowledge of division of rational numbers, in the context of an appropriate taxonomy of the cognitive domain.

2. The final instrument (32-item test) can be assumed to be valid and reliable, because results indicated acceptable reliability for the pilot and field test versions.

3. The preservice elementary teachers with science backgrounds consistently scored higher on the developed test than their liberal arts counterparts. It is concluded, therefore, that not all students receiving an elementary education degree under the present system are equally prepared to teach mathematics in elementary grades; elementary education majors with science backgrounds are better prepared.
The present study was an initial step in conducting research in Thailand on elementary education teacher preparation in the area of mathematics. The research should be extended. The following two sections are presented: (a) recommendations for further study and (b) recommendations for practice.

**Recommendations for Further Study**

1. This study should be replicated using Thai preservice elementary teachers in other areas of Thailand, in order to verify use of the final (32-item) instrument to assess preservice elementary education majors in teachers’ colleges and universities throughout the country.

2. Research should be conducted in which the final (32-item) instrument is administered to novice elementary teachers in Thailand, in order to verify the needs of teacher education in the area of division of rational numbers. If correlation between test scores for successful teachers in the field is found to be high, then the test could be used to assess the status of both preservice and inservice elementary teachers in Thailand.

3. Studies patterned on this investigation should be conducted to determine preservice elementary education teachers’ knowledge of other areas of mathematics presented in the elementary curriculum.

4. A process evaluation should be made to ascertain the aspects of mathematics that are of greatest importance to the teaching of elementary school
children in Thailand. These mathematics subjects should be given the same analytical scrutiny as was focused in this investigation on the division of rational numbers.

5. The same domain structure used for instrument development in this study should be used to develop an instrument to assess the mathematics subject matter knowledge of preservice secondary education teachers.

Recommendations for Practice

1. The teachers' colleges participating in this study, especially Colleges 5, 6, and 8, should utilize the findings to assist faculty in mathematics subject instruction and to review standards for admitting prospective elementary teachers into the program of study.

2. Thailand's Ministry of Education planners and college curriculum specialists should consider the findings of this study when reviewing the current preparation of elementary education teachers in the area of mathematics instruction. The findings of this study suggest that elementary education should be divided into two subcurricula: a curriculum for majors having a science background and a curriculum for majors having a liberal arts background. It would be appropriate for the elementary education curriculum for those with science backgrounds to have specific requirements in mathematics, focus on the mathematics subjects being taught in the elementary grades, and provide for more opportunities (i.e., through Micro Teaching) to acquire teaching skills in the areas of mathematics.
REFERENCES


Stein, M. K., tin, and at the annual meeting of the American Educational Research Association, Boston, MA.


APPENDICES
APPENDIX A

The Wilson Model

The Wilson's model contains four levels of behavior:

A.0 Computation level represents the least complex behaviors which we expect from students as outcomes of instruction in mathematics. The computation level should be described so as to include exercises of simple recall and exercises of routine manipulation. The level represents primarily those outcomes which require no decision making or complex memory.

Computation items are designed to require recall of basic facts and terminology or the manipulation of problem elements according to rules the students presumably have learned. Emphasis is upon knowing and performing operations and not deciding which operations are appropriate.

A.1 Knowledge of specific facts. This could include objectives where the student is expected to reproduce or recognize material in almost exactly the same form as it was presented in the course of study. It could also include fundamental units of knowledge that a student can be reasonably assumed to know because he has been exposed to it over a long period of time.

A.2 Knowledge of terminology. For this knowledge, students should be able to recognize, for instance, an acute, an obtuse, or right angle, in geometry, and in an algebra. They should know what is meant by the instruction, "simplify the expression".

Knowledge of specific facts and knowledge of terminology are required as part of any more complex level of behavior.

A.3 Ability to carry out algorithm. This is the most important subcategory of the computation. This is the ability to manipulate elements of stimulus according to some learned rules. The student is not expected to select the algorithm; such selection involves a certain level of choosing and decision making which appropriately belongs at a more complex level of behavior.

B.0 Comprehension is designed to include a more complex set of behaviors than computation.

Comprehension relates either to recall of concepts and generalizations or to transformation of problem elements from one mode to another. The emphasis is upon demonstrating understanding of concepts and their relationships, not upon using concepts to produce solutions.
B.1 Knowledge of concepts is included as comprehension-level behavior because a concept is an abstraction, and an abstraction theoretically requires some implicit decision making in using a concept or in saying whether an object is an instance of a concept.

B.2 Knowledge of principles, rules, and generalizations. Behaviors are included under comprehension. Assume a correspondence with a course of study.

B.3 Knowledge of mathematical structure is a comprehension level behavior, the properties of number systems and of algebraic structures.

C.0 Application level behaviors involve a sequence of responses from the student.

C.1 The ability to solve routine problems involves selecting and carrying out an algorithm. If the problem is stated verbally, the behavior of solving is preceded by the behavior of formulating the problem in symbolic terms. The sequence can be more complicated using the principle an algorithm or making several calculations.

C.2 The ability to make comparisons is an application-level behavior because the student is expected to recall relevant information, discover relationship, and formulate a decision.

C.3 The ability to analyze data is the third applications category. This is a well-practiced part of the mathematics curriculum. It involves reading and interpreting information, manipulating that information, and making decisions or drawing conclusions as a result.

C.4 The ability to recognize patterns, ismorphisms, and symmetries, may involve recalling relevant information, transforming problem elements, manipulation these elements in a sequence, and recognizing a relationship. It is a sequence of behaviors and rightfully belongs at the application level.

Application items require recall of relevant knowledge, selection of appropriate operations, and performance of the operations. They require the student to use concepts in a specific context and in ways he has presumably practiced.

D.0 Analysis this behavior level is the highest of the cognitive categories, comprising the most complex behaviors. It includes most behaviors described in the Taxonomy (Bloom, 1956). It differs from the application-level or comprehension-level behaviors in that it involves a degree of transfer to a context in which there has been no practice.

D.1 The ability to solve nonroutine problems requires the student to exhibit transfer of previous mathematics learning to a new context.
D.2 The ability to discover relationships requires the restructuring of problem elements in a new way to formulate a relationship. The ability differs from the last ability of the applications level in that the student must discover a new relationship rather than recognize a familiar relationship in new data.

D.3 The ability to construct proofs is an essential analysis-level behavior. The language of proof is the language by which the mathematician presents his work to his colleagues.

D.4 The ability to criticize proofs is an analysis-level behavior. This could be stated more generally as the ability to criticize any mathematical argument.

D.5 The ability to formulate and validate generalizations is included as an analysis-level behavior category. It is similar to some previous analysis categories such as the ability to discover a relationship and to construct a proof to substantiate the discovery.

Analysis items require a nonroutine application of concepts. They may require the detection of relationships, the finding of patterns, and the organization and use of concepts and operations in a nonpracticed context.
APPENDIX B

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APPENDIX C

Domain of Task Items Evaluation

Rater

Direction:

Following are four (4) levels of domains of tasks in the division of rational numbers (Wilson, 1971) which consist of computation, comprehension, application, and analysis. Please mark X in the appropriate space provided on the right-hand side.

-1 means the task item is judged not to be retained.
+1 means the task is judged to be retained.
0 means the task is assigned otherwise.

Note: If you think that there are any other domain of tasks to be added, please write them in the space provided.

Task Items Rating Worksheet

<table>
<thead>
<tr>
<th>Domain of task</th>
<th>-1</th>
<th>0</th>
<th>+1</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Computation Level:</strong></td>
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<tr>
<td>1. Memorize and/or identify the meaning of the terms of division, dividend, divisor, quotient, and remainder.</td>
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<tr>
<td>2. Carry out algorithms of the division of natural number and rational number</td>
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<tr>
<td>3. Carry out algorithms of the division of rational number and rational number</td>
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<tr>
<td>4. Carry out algorithms of the division of rational number and rational number</td>
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Suggestions:
<table>
<thead>
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<th>+1</th>
<th>Note</th>
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</thead>
<tbody>
<tr>
<td><strong>Comprehension Level:</strong></td>
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</tr>
<tr>
<td>1. Relationships among principles, rules, and generalizations of division of rational number</td>
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<tr>
<td>2. Interpret word problem involving division of rational number into the most appropriate number sentence</td>
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<tr>
<td>3. Identify data from word problem</td>
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<tr>
<td>4. The meaning of measurement and partition, or values of multiplication situation</td>
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<td>5. The property of closure of division of rational number</td>
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<tr>
<td>6. Division of rational number distinguished between the effects of zero as a divisor and/or dividend</td>
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<td><strong>Suggestions:</strong></td>
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<tr>
<td><strong>Application Level:</strong></td>
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<tr>
<td>1. Routine problem involving division of rational number</td>
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<tr>
<td>2. Make comparison among rational numbers</td>
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<tr>
<td>3. Estimation on division of rational number</td>
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<td><strong>Suggestions:</strong></td>
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<tr>
<td><strong>Analysis Level:</strong></td>
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<tr>
<td>1. Non-routine problem</td>
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<tr>
<td>2. Discover relationships among parts of division sentence when a part is changed (increased or decreased); what others should be</td>
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<tr>
<td>3. The relationship between division and multiplication</td>
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<tr>
<td><strong>Suggestions:</strong></td>
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</table>
Direction:
Following are behavioral objectives involving division of rational numbers which relate to the domain of task items at each of the four levels recommended by Wilson (1971). Please mark X in the appropriate space provided on the right-hand side.

-1 means the task item is judged not to be retained.
+1 means the task is judged to be retained.
0 means the task is assigned otherwise.

Note: If you think that there are any other appropriate objectives which need to be added, please write them in the space provided.

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<tbody>
<tr>
<td>Computation Level:</td>
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</tr>
<tr>
<td>1. The student will be able to identify the terms of division in various contexts (i.e., dividend, divisor, quotient, and remainder)</td>
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<tr>
<td>Suggestion:</td>
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<tr>
<td>2. The student will be able to carry out algorithms of division of the following:</td>
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<tr>
<td>- natural number by rational number</td>
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<tr>
<td>- rational number by natural number</td>
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<tr>
<td>- rational number by rational number</td>
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<tr>
<td>Suggestion:</td>
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Behavioral Objective Items Rating Worksheet continued

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<tr>
<td><strong>Comprehension Level:</strong></td>
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<tr>
<td>1. Given several examples involving division of rational numbers, the student will be able to select an appropriate symbolic sentence with the same meaning ..................................................</td>
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<tr>
<td>Suggestion:</td>
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<tr>
<td>2. Given a division sentence with rational number and rational number, the student will be able to identify the multiplication sentence which is most closely related to it ..............................................</td>
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<tr>
<td>Suggestion:</td>
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<tr>
<td>3. Given a division sentence with rational number and rational numbers, the student will be able to select an appropriate answer of the multiplication sentence which is most closely related to it ..............................................</td>
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<tr>
<td>Suggestion:</td>
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<tr>
<td>4. Given a word problem involving division of natural or rational numbers with extraneous information, the student will be able to identify the data necessary for the solution of the problem</td>
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<tr>
<td>Suggestion:</td>
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<tr>
<td>5. Given a word problem involving division of natural and/or rational numbers, the student will be able to select the most appropriate symbolic sentence for obtaining the solution ..................................................</td>
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<tr>
<td>Suggestion:</td>
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<tr>
<td>6. Given the meaning of partition and measurement along with word problem involving division of natural and/or rational numbers, the student will be able to classify subsequent problems accordingly ..................................................</td>
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<tr>
<td>Suggestion:</td>
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<tr>
<td>Behavioral Objective</td>
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<td>Note</td>
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<tr>
<td>7. The student will be able to demonstrate understanding of closure law by identifying sets as closed or not closed with the operation of division</td>
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<tr>
<td>Suggestion:</td>
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<tr>
<td>8. The student will be able to select the most appropriate explanation of the quotient when the dividend and/or divisor is zero</td>
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<tr>
<td>Suggestion:</td>
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</table>

**Application Level:**

1. Student will be able to find the solution from a given routine word problem which is solvable by dividing with natural and/or rational numbers.

   Suggestion: |

2. Given various numerals for rational numbers, the student will be able to place those numbers into the correct order (increasing or decreasing).

   Suggestion: |

3. Student will be able to select an appropriate estimate of the solution from a given word problem involving division of natural and/or rational numbers, where the numbers are very large (nine digits) for pencil and paper computation.

   Suggestion: |
Behavioral Objective Items Rating Worksheet continued

<table>
<thead>
<tr>
<th>Analysis Level:</th>
<th>-1</th>
<th>0</th>
<th>+1</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The student will be able to find a solution from a given non-routine word problem involving the type which includes division of natural and/or rational numbers.</td>
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<tr>
<td>Suggestion:</td>
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<tr>
<td>2. The student will be able to select an answer from a given division sentence which has various parts when one part is changed (increased or decreased) what would happen to others.</td>
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<tr>
<td>Suggestion:</td>
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<tr>
<td>3. The student will be able to select an appropriate phrase that division of rational numbers can be accomplished by multiplying the dividend by the reciprocal of the divisor.</td>
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<tr>
<td>Suggestion:</td>
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</tbody>
</table>
### APPENDIX E

Results of Task Items Evaluation

<table>
<thead>
<tr>
<th>Item</th>
<th>Ratings</th>
<th>Items with +1 Rating</th>
</tr>
</thead>
<tbody>
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<td></td>
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<tr>
<td>1</td>
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**Note.** Task items with +1 ratings ≥ 80% were retained.
APPENDIX F

Results of Objective Items Evaluation

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Note. Objective items with +1 ratings ≥80% were retained. It was suggested that Item 5 be combined with Item 4.
APPENDIX G

Results of Screening Test Items (Computation)

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Note. Items with 70% of ratings ≥4 were retained.
APPENDIX H

Results of Screening Test Items (Comprehension)

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Note. Items with 70% of ratings ≥3 were retained.
APPENDIX I

Results of Screening Test Items (Application)

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*Note.* Items with 70% of ratings ≥3 were retained.
### APPENDIX J

**Results of Screening Test (Analysis)**

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**Note.** Items with 70% of ratings ≥3 were retained.
APPENDIX K

Field Test Instrument (English Version)

The Test of Division of Rational Numbers

College Name:_________________________ Control No._______

High School Background (please mark one):  ○ Science  ○ Liberal Arts

Direction:

1. This test consists of 4 sections (section 1, section 2, section 3, and section 4).

2. Each section has the following items:
   2.1 Section has 10 items.
   2.2 Section 2 has 10 items.
   2.3 Section 3 has 12 items.
   2.4 Section 4 has 10 items.

3. Each test item has five (5) options with one correct answer.

4. Please select the answer which is the most appropriate and mark X on the answer sheet provided. If you want to change the answer, please cross out and select another answer.

Please take your time and do your best.

Thank you for your cooperation.
Section 1

1. What is the answer to $4 \ 1/2 \div 3 = \square$?
   a. $4 \ 1/6$
   b. $1 \ 1/2$
   c. $5 \ 1/2$
   d. $2/3$
   e. $13 \ 1/2$

2. What is the answer of $6.2 \div 3131$?
   a. 5050
   b. 0.505
   c. 505
   d. 5.05
   e. 50.5

3. What is the answer of $0.07 \div 0.028$?
   a. 0.0004
   b. 0.004
   c. 0.04
   d. 0.4
   e. 4.0

4. What is the result of 6 divided by $1/3$?
   a. 18
   b. $1/18$
   c. 2
   d. $1/2$
   e. 3

5. What is the answer of $4 \div 3/4 = \square$?
   a. 16
   b. $3/16$
   c. 3
   d. $3/4$
   e. $5 \ 1/3$

6. $8 \div 432$
   What is the number 54 for the division above?
   a. quotient
   b. remainder
   c. divisor
   d. dividend
   e. denominator
7. What is the result of 12 divided by 1/2?
   a. 24
   b. 6
   c. 1/24
   d. 1/6
   e. 7

8. What is the answer for \(5 \div \frac{7}{2} = \square\)?
   a. \(\frac{2}{3}\)
   b. \(1 \frac{1}{2}\)
   c. 6
   d. \(\frac{1}{6}\)
   e. \(35 \frac{1}{2}\)

9. \(20 \div 1.5 = \square\)?
   a. 1.3
   b. 1.33
   c. 13.3
   d. 13.33
   e. 13.333

10. \(12.5 \div 0.05 = \square\)?
    a. 0.25
    b. 2.50
    c. 25.0
    d. 250.0
    e. 2500.0
Section 2

11. What is the multiplication sentence most closely related to the division sentence \(7/8 \div 14 = \square\)?
   a. \(14 \times \square = 7/8\)
   b. \(\square \times 7/8 = 14\)
   c. \(14 \times 7/8 = \square\)
   d. \(14 \times 8/7 = \square\)
   e. \(14 \times \square = 8/7\)

12. If \(5/6 \div 4/5 = \square\), then what is the result to be filled in \(\square\)?
   a. \(6/5 \times 5/4 = \square\)
   b. \(6/5 \times 4/5 = \square\)
   c. \(5/5 \times 4/6 = \square\)
   d. \(5/6 \times 4/5 = \square\)
   e. \(5/6 \times 5/4 = \square\)

13. Pafan drives round trip from Bangkok to Songkla averaging 75 kilometers per hour. She buys 35.6 liters of gasoline at Prajuabkirikan. The 832 kilometers takes a little more than 11 hours. If she used 92.3 liters of gasoline, what is Pafan's average of gasoline in kilometers per liters?
   a. 75 kph, 832 kilometers, 35.6 liters of gasoline
   b. 832 kilometers, 11 hours
   c. 92.3 liters of gasoline, 832 kilometers
   d. 832 kilometers, 75 kph
   e. 92.3 of gasoline, 11 hours

14. A rope 3 1/2 feet long is to be partitioned into 30 shorter pieces. How many inches long will each of the shorter pieces be?
   a. \((3 1/2 \times 30) \div 12 = \square\)
   b. \(3 1/2 \div (30 \div 12) = \square\)
   c. \((3 1/2 \times 30) \div 12 = \square\)
   d. \(30 \div (3 1/2 \times 12) = \square\)
   e. \((3\frac{1}{2} \times 12) \div 30 = \square\)

15. What is the most appropriate explanation of \(0 \div 8 = \square\)?
   a. \(0 \div 8 = 0\), because all division into 0 results in 0.
   b. \(0 \div 8\) is undefined because all division involving 0 is undefined.
   c. \(0 \div 8\) is undefined because zero is nothing.
   d. \(0 \div 8 = 8\) because zero is no value.
   e. \(0 \div 8\); cannot find the answer because zero has the least value.
16. Which of the following is the most appropriate argument that shows the division of $1/2 \div 3/8$?
   a. $1/2 \div 3/8 = 3/16 = 1/2 \times 3/8 = 1/2 \times 8/3$
   b. $1/2 = (1 \div 3)/(2 \div 8) = (1 \times 3)/(2 \times 8) = 1/2 \times 8/3$
   c. $1/2 \div 3/8 = 3/2 \div 1/8 = (3 \div 1)/(2 \div 8) = 3/16 = 3/2 \times 1/8 = (1 \times 8)/(2 \times 3) = 1/2 \times 8/3$
   d. $1/2 \div 3/8 = 1/2/3/8 \times 8/3/8/3 = (1/2 \times 8/3)/1 = 1/2 \times 8/3$
   e. none of the above

17. Which of the following is equivalent to $7 \div 2/3 = ?$
   a. $7 \times 2/3 = \square$
   b. $7 \times 2/3 = \square$
   c. $1/7 \times 2/3 = \square$
   d. $1/7 \times 3/2 = \square$
   e. $7/3 \times 2 = \square$

18. What is the most appropriate explanation of the division $2/3 \div 0 = ?$
   a. $2/3 \div 0 = 0$, because all division with 0 results in 0.
   b. $2/3 \div 0$ is undefined because zero is nothing.
   c. $2/3 \div 0$ is undefined because there is no number such that 0 times the numbers is 2/3.
   d. $2/3 \div 0 = 2/3$, because zero is nothing.
   e. $2/3 \div 0$; cannot find its value because zero is less than the dividend.

19. Which of the following multiplication sentences is closely related to the division sentence of $3/8 \div 5 = ?$
   a. $3/8 \times 5 = \square$
   b. $8/3 \times 5 = \square$
   c. $8/3 \times 1/5 = \square$
   d. $8/3 \times 5 = \square$
   e. $3 \times 5/8 = \square$

20. Which of the following multiplication sentence is closely related to the division sentence of $2/3 \div 5/8 = ?$
   a. $2/3 \times 5/8 = \square$
   b. $2/3 \times 8/5 = \square$
   c. $3/2 \times 5/8 = \square$
   d. $3/2 \times 8/5 = \square$
   e. $3/5 \times 8/2 = \square$
Section 3

21. Taewee must deliver 14 tons of rambutans. If her truck can carry 3 tons at a time, how many trips must she make to finish delivery?
   a. 4 trips, remainder 2 tons
   b. 4 trips
   c. 4 2/3 trips
   d. 5 trips
   e. 42 trips

22. Which of the following numbers are in the order from the smallest to the largest?
   a. $\frac{43}{128}$, $\frac{21}{64}$, $\frac{13}{32}$, $\frac{11}{16}$
   b. $\frac{11}{16}$, $\frac{13}{32}$, $\frac{21}{64}$, $\frac{43}{128}$
   c. $\frac{11}{16}$, $\frac{21}{64}$, $\frac{43}{128}$, $\frac{13}{32}$
   d. $\frac{21}{64}$, $\frac{43}{128}$, $\frac{13}{32}$, $\frac{11}{16}$
   e. $\frac{43}{128}$, $\frac{13}{32}$, $\frac{21}{64}$, $\frac{11}{16}$

23. Last year, Chokewatana Corporation sold 5,204 pieces of furniture for a total amount of 1,533,662.28 bahts. What was the average price of each piece?
   a. 100 bahts
   b. 200 bahts
   c. 300 bahts
   d. 400 bahts
   e. 500 bahts

24. Jongdee’s house will take 40 5/8 hours to paint. She works 6 1/2 hours per day. How many days will it take to finish the job?
   a. 7 days
   b. 6 1/4 days
   c. 6 days
   d. 5 3/4 days
   e. 8 days

25. Which of the following numbers are in the order from smallest to largest?
   a. 4, 3.8, 3.12, 3.256, 3.4175
   b. 3.8, 3.12, 3.256, 3.4175, 4
   c. 3.12, 3.8, 3.256, 3.1475, 4
   d. 3.12, 3.256, 3.1475, 3.8, 4
   e. 3.1475, 3.256, 3.12, 3.8, 4
26. Darlin and her space shuttle crew made 390 orbits of the earth in 24 days, 6 hours, and 37 minutes. What is the average time for an orbit?
   a. 1 1/2 hours
   b. 15 hours
   c. 2 1/2 hours
   d. 25 hours
   e. 3 1/2 hours

27. Chalee drives a car 654 kilometers on 2/3 of a tank of fuel. How many kilometers will the car go on a full tank?
   a. 490.5 km
   b. 872.0 km
   c. 817.5 km
   d. 523.2 km
   e. 942.2 km

28. Which of the following numbers are in the order from largest to smallest?
   a. 9/16, 3/8, 1/2, 11/32
   b. 11/32, 9/16, 3/8, 1/2
   c. 1/2, 3/8, 9/16, 11/32
   d. 11/32, 1/2, 3/8, 9/16
   e. 9/16, 1/2, 3/8, 11/32

29. Anon drove 1,178 miles in 19 hours, 34 minutes, and 47 seconds. What was his average in miles per hour?
   a. 40 mph
   b. 60 mph
   c. 80 mph
   d. 90 mph
   e. 100 mph

30. How many pieces will 20 kilograms of meat (salty beef) make, if each piece weighs 5/16 kilograms?
   a. 6 1/4 pieces
   b. 1/64 piece
   c. 64 pieces
   d. 6 pieces
   e. 24 pieces

31. Which of the following numbers are in order from largest to smallest?
   a. 5/32, 11/16, 7/8, 3/4
   b. 11/16, 7/8, 5/32, 3/4
   c. 7/8, 3/4, 11/16, 5/32
   d. 3/4, 7/8, 11/16, 5/32
   e. 3/4, 5/32, 7/8, 11/16
32. Navin rode his bike from Choomporn to Chiangrai for a distance of 1,438 kilometers within 28 days. What was the average distance per day?
   a. 20 kilometers
   b. 30 kilometers
   c. 40 kilometers
   d. 50 kilometers
   e. 60 kilometers

Section 4

33. Malee rides her bike 12 miles at 12 mph, then 36 miles at 18 mph. What is her average speed? (average speed for a trip is total distance divided by total time)
   a. 12 mph
   b. 13 mph
   c. 14 mph
   d. 15 mph
   e. 16 mph

34. If the division sentence $\frac{1}{5} \div \frac{3}{8} = \frac{8}{15}$ is true, what must happen to the $\frac{1}{5}$ if $\frac{3}{8}$ is increased while the $\frac{8}{15}$ remains constant?
   a. increase
   b. decrease
   c. stay the same
   d. cannot tell because all values are constant.
   e. none of the above because there is no unknown term.

35. To prove the "invert and multiply" rule for division of rational numbers, it is necessary to do the following:
   a. give at least three positive examples
   b. give one counter-example
   c. show the rule that can be derived in logical steps
   d. prove by subtracting one at a time
   e. compare to the division of rational numbers

36. Nil and Bai are paid 500 bahts to paint a house. Nil estimates that she could paint the house herself in 5 days. Bai is sure that she could do it by herself in 7 days. If both of these estimates are correct, how long will it take them if they work together?
   a. 6 days
   b. 12 days
   c. less than 3 days
   d. between 3 and 4 days
   e. between 4 and 5 days
37. In the division sentence \( \frac{1}{2} \div \frac{3}{4} = \frac{2}{3} \), if the \( \frac{3}{4} \) is increased while the \( \frac{1}{2} \) remains constant, what must happen to the \( \frac{2}{3} \) for the sentence to remain true?

a. increase  

b. decrease  

c. stay the same  

d. cannot tell because all values are constant  

e. none of the above because there is no unknown term

38. Dang and Dum are paid according to the amount of work they do. A certain job would take Dang 10 hours while Dum could do it in 8 hours. If they work together and are paid 900 bahts for the job, How many baths will each person receive?

a. Dang 450 bahts, Dum 450 bahts  

b. Dang 500 bahts, Dum 400 bahts  

c. Dang 400 bahts, Dum 500 bahts  

d. Dang 600 bahts, Dum 300 bahts  

e. Dang 550 bahts, Dum 350 bahts

39. In any true division sentence, what must be happen if the divisor of the quotient remains the same while the dividend is decreased?

a. increase  

b. decrease  

c. stay the same  

d. cannot tell, no data  

e. none of the above, no unknown term

40. Which of the following is an appropriate formal argument for the "invert and multiply" rule for division of rational numbers?

a. \( \frac{a}{b} \div \frac{c}{d} = \frac{a}{b} \cdot \frac{d}{c} \)  

b. \( \frac{a}{b} \div \frac{c}{d} = \frac{a}{c} \)  

c. \( \frac{a}{b} \div \frac{c}{d} = \frac{(c/d)/(b/a)}{(b/a \cdot (c/d)/(a/b))} = \frac{(b/a \cdot c/d)/(b/a \cdot a/b)}{b/a \cdot c/d} = \frac{b/a \cdot c/d}{b/a \cdot c/d} \)  

d. \( \frac{a}{b} \div \frac{c}{d} = \frac{(a/b)/(c/d)}{(d/c)/(d/c)} = \frac{a/b \cdot d/c}{1} = \frac{a/b \cdot d/c}{1} = \frac{a/b \cdot d/c}{1} \)  

e. \( \frac{a}{b} \div \frac{c}{d} = \frac{(c/d)/(a/b)}{(b/a \cdot (c/d)/(a/b))} = \frac{(a/b \cdot d/c)/(c/d \cdot d/c)}{a/b \cdot d/c} \)  

41. 9.9356 divided by 4.21 equals 2.36. If the sentence is true, the dividend is decreased while the divisor remains constant. What must happen to the quotient?

a. increase  

b. decrease  

c. stay the same  

d. cannot tell because the constant cannot change  

e. none of the above because there is no unknown term
42. Which of the following is an appropriate formal argument for the "invert and multiply" rule for the division of rational numbers?

a. \( \frac{x}{y} \div \frac{z}{w} = \frac{x}{y} \cdot \frac{w}{z} \)

b. \( \frac{x}{z} \div \frac{y}{z} = \frac{x}{y} \)

c. \( \frac{x}{y} \div \frac{z}{w} = \frac{(x/y)/(z/w)}{\frac{(z/w)/(w/z)}} = \frac{(x/y \cdot w/z)/(z/w \cdot w/z)}{w/z} = \frac{(x/y \cdot w/z)}{w/z} = \frac{x/y \cdot w/z}{w/z} = x/y \cdot w/z \)

d. \( \frac{x}{y} \div \frac{z}{w} = \frac{(z/w)/(x/y)}{\frac{(y/x)/(z/w)}} = \frac{(y/x \cdot z/w)/(y/x \cdot x/y)}{z/w} = \frac{(y/x \cdot z/w)}{z/w} = \frac{y/x \cdot z/w}{z/w} = y/x \cdot z/w \)

e. \( \frac{x}{y} \div \frac{y}{z} = \frac{x}{z} \)
APPENDIX L

Point-Biserial Data for Computation Items (Field Test)

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APPENDIX M

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APPENDIX O

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## APPENDIX P

Intercorrelations of the Field Test Data

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<th>Section 3 Application</th>
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APPENDIX Q

Factor Analysis Results for Computation Level (Field Test)

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Note. n = 32.
APPENDIX R

Factor Analysis Results for Comprehension Level (Field Test)

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Note. n = 32.
APPENDIX S

Factor Analysis Results for Application Level (Field Test)

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Note. n = 32.
APPENDIX T

Factor Analysis Results for Analysis Level (Field Test)

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Note. n = 32. Item 34, with a loading of .621, overlapped as a part of subfactor 1.
APPENDIX U

Final Instrument (English Version)

The Test of Division of Rational Numbers

College Name: ____________________________  Control No. _______

High School Background (please mark one):  ○ Science  ○ Liberal Arts

Direction:

1. This test consists of 4 sections (section 1, section 2, section 3, and section 4).

2. Each section has the following items:
   2.1 Section has 8 items.
   2.2 Section 2 has 8 items.
   2.3 Section 3 has 10 items.
   2.4 Section 4 has 6 items.

3. Each test item has five (5) options with one correct answer.

4. Please select the answer which is the most appropriate and mark X on the answer sheet provided. If you want to change the answer, please cross out and select another answer.

Please take your time and do your best.

Thank you for your cooperation.
Section 1

1. What is the answer to $4\frac{1}{2} \div 3 = \square$?
   a. $4\frac{1}{6}$
   b. $1\frac{1}{2}$
   c. $5\frac{1}{2}$
   d. $2/3$
   e. $13\frac{1}{2}$

2. What is the answer of $0.07 \div 0.028$?
   a. $0.0004$
   b. $0.004$
   c. $0.04$
   d. $0.4$
   e. $4.0$

3. What is the result of $6$ divided by $1/3$?
   a. $18$
   b. $1/18$
   c. $2$
   d. $1/2$
   e. $3$

4. What is the answer of $4 \div 3/4 = \square$?
   a. $16$
   b. $3/16$
   c. $3$
   d. $3/4$
   e. $5\frac{1}{3}$

5. What is the result of $12$ divided by $1/2$?
   a. $24$
   b. $6$
   c. $1/24$
   d. $1/6$
   e. $7$

6. What is the answer for $5 \div 7\frac{1}{2} = \square$?
   a. $2/3$
   b. $1\frac{1}{2}$
   c. $6$
   d. $1/6$
   e. $35\frac{1}{2}$
7. \[20 \div 1.5 = ?\]
   a. 1.3
   b. 1.33
   c. 13.3
   d. 13.33
   e. 13.333

8. \[12.5 \div 0.05 = ?\]
   a. 0.25
   b. 2.50
   c. 25.0
   d. 250.0
   e. 2500.0

Section 2

9. If \(\frac{5}{6} \div \frac{4}{5}\) = \(\square\) then what is the result to be filled in?
   a. \(\frac{6}{5} \times \frac{5}{4} = \square\)
   b. \(\frac{6}{5} \times \frac{4}{5} = \square\)
   c. \(\frac{5}{5} \times \frac{4}{6} = \square\)
   d. \(\frac{5}{6} \times \frac{4}{5} = \square\)
   e. \(\frac{5}{6} \times \frac{5}{4} = \square\)

10. Pafan drives round trip from Bangkok to Songkla averaging 75 kilometers per hour. She buys 35.6 liters of gasoline at Prajuabkirikan. The 832 kilometers takes a little more than 11 hours. If she used 92.3 liters of gasoline, what is Pafan’s average of gasoline in kilometers per liters?
   a. 75 kph, 832 kilometers, 35.6 liters of gasoline
   b. 832 kilometers, 11 hours
   c. 92.3 liters of gasoline, 832 kilometers
   d. 832 kilometers, 75 kph
   e. 92.3 liters of gasoline, 11 hours

11. A rope \(3\frac{1}{2}\) feet long is to be partitioned into 30 shorter pieces. How many inches long will each of the shorter pieces be?
   a. \((3 \frac{1}{2} \times 30) \div 12 = \square\)
   b. \(3 \frac{1}{2} \div (30 \div 12) = \square\)
   c. \((3\frac{1}{2} \times 30) \div 12 = \square\)
   d. \(30 \div (3\frac{1}{2} \times 12) = \square\)
   e. \((3 \frac{1}{2} \times 12) \div 30 = \square\)
12. What is the most appropriate explanation of \( 0 \div 8 = \)\( \Box \)?
   a. \( 0 \div 8 = 0 \), because all division into 0 results in 0.
   b. \( 0 \div 8 \) is undefined because all division involving 0 is undefined.
   c. \( 0 \div 8 \) is undefined because zero is nothing.
   d. \( 0 \div 8 = 8 \) because zero is no value.
   e. \( 0 \div 8 \); cannot find the answer because zero has the least value.

13. Which of the following is the most appropriate argument that shows the division of \( \frac{1}{2} \div \frac{3}{8} \)?
   a. \( \frac{1}{2} \div \frac{3}{8} = \frac{3}{16} = \frac{1}{2} \times \frac{3}{8} = \frac{1}{2} \times \frac{8}{3} \)
   b. \( \frac{1}{2} = \frac{(1 + 3)}{(2 + 8)} = \frac{(1 \times 3)}{(2 \times 8)} = \frac{1}{2} \times \frac{8}{3} \)
   c. \( \frac{1}{2} \div \frac{3}{8} = \frac{3}{2} \div \frac{1}{8} = \frac{(3 \div 1)}{(2 \div 8)} = \frac{3}{16} = \frac{3}{2} \times \frac{1}{8} = \frac{(1 \times 8)}{(2 \times 3)} = \frac{1}{2} \times \frac{8}{3} \)
   d. \( \frac{1}{2} \div \frac{3}{8} = \frac{1}{2/3/8} \times \frac{8/3/8/3} = \frac{(1/2 \times 8/3)}{1} = \frac{1}{2} \times \frac{8}{3} \)
   e. none of the above

14. Which of the following is equivalent to \( 7 \div \frac{2}{3} = \)\( \Box \)?
   a. \( 7 \times \frac{2}{3} = \)
   b. \( 7 \times \frac{2}{3} = \)
   c. \( \frac{1}{7} \times \frac{2}{3} = \)
   d. \( \frac{1}{7} \times \frac{3}{2} = \)
   e. \( \frac{7}{3} \times 2 = \)

15. Which of the following multiplication sentences is closely related to the division sentence of \( \frac{3}{8} \div 5 = \)\( \Box \)?
   a. \( \frac{3}{8} \times 5 = \)
   b. \( \frac{8}{3} \times 5 = \)
   c. \( \frac{8}{3} \times \frac{1}{5} = \)
   d. \( \frac{8}{3} \times \frac{5}{3} = \)
   e. \( \frac{3}{5} \times \frac{8}{3} = \)

16. Which of the following multiplication sentence is closely related to the division sentence of \( \frac{2}{3} \div \frac{5}{8} = \)\( \Box \)?
   a. \( \frac{2}{3} \times \frac{5}{8} = \)
   b. \( \frac{2}{3} \times \frac{8}{5} = \)
   c. \( \frac{3}{2} \times \frac{5}{8} = \)
   d. \( \frac{3}{2} \times \frac{8}{5} = \)
   e. \( \frac{3}{5} \times \frac{8}{2} = \)
Section 3

17. Taewee must deliver 14 tons of rambutans. If her truck can carry 3 tons at a time, how many trips must she make to finish delivery?
   a. 4 trips, remainder 2 tons
   b. 4 trips
   c. 4 2/3 trips
   d. 5 trips
   e. 42 trips

18. Last year, Chokewatana Corporation sold 5,204 pieces of furniture for a total amount of 1,533,662.28 bahts. What was the average price of each piece?
   a. 100 bahts
   b. 200 bahts
   c. 300 bahts
   d. 400 bahts
   e. 500 bahts

19. Jongdee’s house will take 40 5/8 hours to paint. She works 6 1/2 hours per day. How many days will it take to finish the job?
   a. 7 days
   b. 6 1/4 days
   c. 6 days
   d. 5 3/4 days
   e. 8 days

20. Which of the following numbers are in the order from smallest to largest?
   a. 4, 3.8, 3.12, 3.256, 3.4175
   b. 3.8, 3.12, 3.256, 3.4175, 4
   c. 3.12, 3.8, 3.256, 3.1475, 4
   d. 3.12, 3.256, 3.1475, 3.8, 4
   e. 3.1475, 3.256, 3.12, 3.8, 4

21. Darlin and her space shuttle crew made 390 orbits of the earth in 24 days, 6 hours, and 37 minutes. What is the average time for an orbit?
   a. 1 1/2 hours
   b. 15 hours
   c. 2 1/2 hours
   d. 25 hours
   e. 3 1/2 hours
22. Chalee drives a car 654 kilometers on 2/3 of a tank of fuel. How many kilometers will the car go on a full tank?
   a. 490.5 km
   b. 872.0 km
   c. 817.5 km
   d. 523.2 km
   e. 942.2 km

23. Anon drove 1,178 miles in 19 hours, 34 minutes, and 47 seconds. What was his average in miles per hour?
   a. 40 mph
   b. 60 mph
   c. 80 mph
   d. 90 mph
   e. 100 mph

24. A salty beef used 5/16 kilograms per piece. How many pieces will it make from 20 kilograms of meat?
   a. 6 1/4 pieces
   b. 1/64 piece
   c. 64 pieces
   d. 6 pieces
   e. 24 pieces

25. Which of the following numbers are in order from largest to smallest?
   a. 5/32, 11/16, 7/8, 3/4
   b. 11/16, 7/8, 5/32, 3/4
   c. 7/8, 3/4, 11/16, 5/32
   d. 3/4, 7/8, 11/16, 5/32
   e. 3/4, 5/32, 7/8, 11/16

26. Navin rode his bike from Choomporn to Chiangrai for a distance of 1,438 kilometers within 28 days. What was the average distance per day?
   a. 20 kilometers
   b. 30 kilometers
   c. 40 kilometers
   d. 50 kilometers
   e. 60 kilometers
Section 4

27. To prove the “invert and multiply” rule for division of rational numbers, it is necessary to do the following:
   a. give at least three positive examples
   b. give one counter-example
   c. show the rule that can be derived in logical steps
   d. prove by subtracting one at a time
   e. compare to the division of rational numbers

28. In the division sentence \( \frac{1}{2} \div \frac{3}{4} = \frac{2}{3} \), if the \( \frac{3}{4} \) is increased while the \( \frac{1}{2} \) remains constant, what must happen to the \( \frac{2}{3} \) for the sentence to remain true?
   a. increase
   b. decrease
   c. stay the same
   d. cannot tell because all values are constant
   e. none of the above because there is no unknown term

29. In any true division sentence, what must happen if the divisor of the quotient remains the same while the dividend is decreased?
   a. increase
   b. decrease
   c. stay the same
   d. cannot tell, no data
   e. none of the above, no unknown term

30. Which of the following is an appropriate formal argument for the “invert and multiply” rule for division of rational numbers?
   a. \( \frac{a}{b} \div \frac{c}{d} = \frac{a}{b} \cdot \frac{d}{c} \)
   b. \( \frac{a}{b} \div \frac{c}{d} = \frac{a}{c} \)
   c. \( \frac{a}{b} \div \frac{c}{d} = \frac{(c/d)/(b/a)}{(a/b)/(c/d)} = \frac{(b/a \cdot c/d)}{(b/a \cdot a/b)} = \frac{b/a \cdot c/d}{b/a \cdot a/b} = \frac{b/a \cdot c/d}{1} = \frac{b/a \cdot c/d}{1} \)
   d. \( \frac{a}{b} \div \frac{c}{d} = \frac{(a/b)/(c/d)}{(d/c)/(b/a)} = \frac{(b/a \cdot d/c)}{(d/c)/(b/a)} = \frac{(b/a \cdot d/c)}{1} = \frac{b/a \cdot d/c}{1} \)
   e. \( \frac{a}{b} \div \frac{c}{d} = \frac{(c/d)/(a/b)}{(a/b)/(c/d)} = \frac{(b/a \cdot d/c)}{(d/c)/(b/a)} = \frac{(b/a \cdot d/c)}{1} = \frac{b/a \cdot d/c}{1} \)

31. 9.9356 divided by 4.21 equals 2.36. If that sentence is true, the dividend is decreased while the divisor remains constant. What must happen to the quotient?
   a. increase
   b. decrease
   c. stay the same
   d. cannot tell because the constant cannot change
   e. none of the above because there is no unknown term
Which of the following is an appropriate formal argument for the “invert and multiply” rule for the division of rational numbers?

a. \( \frac{x}{y} \div \frac{z}{w} = \frac{x}{y} \cdot \frac{w}{z} \)

b. \( \frac{x}{z} \div \frac{y}{z} = \frac{x}{y} \)

c. \( \frac{x}{y} \div \frac{z}{w} = \left( \frac{x}{y} \right) \left( \frac{z}{w} \right) = \left( \frac{x}{y} \right) \left( \frac{z}{w} \right) \left( \frac{w}{z} \right) \left( \frac{w}{z} \right) = \left( \frac{x}{y} \cdot \frac{w}{z} \right) \left( \frac{w}{z} \right) = \frac{x}{y} \cdot \frac{w}{z} \)

d. \( \frac{x}{y} \div \frac{z}{w} = \left( \frac{z}{w} \right) \left( \frac{x}{y} \right) = \left( \frac{y}{x} \right) \left( \frac{x}{y} \right) \left( \frac{z}{w} \right) \left( \frac{x}{y} \right) = \left( \frac{y}{x} \cdot \frac{z}{w} \right) \left( \frac{y}{x} \cdot \frac{x}{y} \right) = \frac{y}{x} \cdot \frac{z}{w} \)

e. \( \frac{x}{y} \div \frac{y}{z} = \frac{x}{z} \)
APPENDIX V

Final Instrument (Thai Version)

แบบทดสอบเรื่องการจราจรบนถนน

ชั้นสัญญาณ................................................................. หมายเลขสอบ ...........................................................

ท่านจงเขียนปลายคำตอบ (โปรดกรอก X ลงใน O) O วิทยาศาสตร์ O ติวทฤษฎี

คำชี้แจงในการจ้างแบบทดสอบ

1. แบบทดสอบนี้ประกอบด้วย 4 ตอน (ตอนที่ 1, ตอนที่ 2, ตอนที่ 3, ตอนที่ 4)
2. แต่ละตอนประกอบด้วยบัตรแนวข้อต่อไปนี้
   2.1 ตอนที่ 1 มี 8 ข้อ
   2.2 ตอนที่ 2 มี 8 ข้อ
   2.3 ตอนที่ 3 มี 10 ข้อ
   2.4 ตอนที่ 4 มี 6 ข้อ
3. แบบทดสอบแต่ละตอนประกอบด้วย 5 ตัวเลือก ซึ่งมีตัวเลือกเฉลี่ย 1 ตัวเลือก
4. โปรดเลือกคำตอบที่ให้ความถูกต้องกับข้อที่แสดงเจาะจงละเอียดโดยพิจารณาเป็นหน่วย

ประกอบการเฉลยคำตอบ หากตอบถูกจะมีคะแนน แต่ถ้าตอบผิดจะไม่ได้

-------------------------------------------------------------------------------------------------

โปรดทำความเข้าใจตามแนวที่กำหนด

ขอขอบคุณที่ให้ความร่วมมือ
1. $4 \frac{1}{2} + 3$  ผลลัพธ์ที่ถูกต้อง
   ก. $4 \frac{1}{6}$
   ข. $1 \frac{1}{2}$
   ค. $5 \frac{1}{2}$
   ง. $3 \frac{1}{2}$
   จ. $13 \frac{1}{2}$

2. $0.07 \div 0.028$  ผลลัพธ์ที่ถูกต้อง
   ก. 0.0004
   ข. 0.004
   ค. 0.04
   ง. 0.4
   จ. 4.0
3. 6 หารด้วย $\frac{1}{3}$ มีตัวคำตอบ

ก. 18

ข. $\frac{1}{18}$

ค. 2

ง. $\frac{1}{2}$

จ. 3

4. $4 + \frac{3}{4} = \square$ คำตอบตรงกับบันได

ก. 1

ข. $\frac{3}{16}$

ค. 3

ง. $\frac{1}{3}$

จ. $5 \frac{1}{3}$

5. 12 หารด้วย $\frac{1}{2}$ มีตัวคำตอบ

ก. 24

ข. 6

ค. $\frac{1}{24}$

ง. $\frac{1}{6}$

จ. 7
6. \( 5 + 7 \frac{1}{2} = \) คัดตอบตรงกันขึ้นได้

น 2
บ 1 \( \frac{1}{2} \)
ค 6
ง 1 \( \frac{1}{6} \)
จ 35 \( \frac{1}{2} \)

7. \( 20 + 1.5 = \) คัดตอบตรงกันขึ้นได้

น 1.3
บ 1.33
ค 13.3
ง 13.33
จ 13.333

8. \( 12.5 + 0.05 = \) คัดตอบตรงกันขึ้นได้

น 0.25
บ 2.50
ค 25.0
ง 250.0
จ 2500.
9.  

\[ \frac{5}{6} \div \frac{4}{5} = \boxed{\text{numerator}} \text{ แล้ว ผลหารที่ได้ลงใน } \boxed{\text{denominator}} \text{ จะเท่ากับผลคูณในรูปใด}{/p} 

a. \[ \frac{6}{5} \times \frac{5}{4} = \boxed{\text{numerator}} \text{ ผลหารที่ได้ลงใน } \boxed{\text{denominator}} \text{ จะเท่ากับผลคูณในรูปใด}{/p} 

b. \[ \frac{6}{5} \times \frac{4}{5} = \boxed{\text{numerator}} \text{ ผลหารที่ได้ลงใน } \boxed{\text{denominator}} \text{ จะเท่ากับผลคูณในรูปใด}{/p} 

c. \[ \frac{5}{4} \times \frac{4}{6} = \boxed{\text{numerator}} \text{ ผลหารที่ได้ลงใน } \boxed{\text{denominator}} \text{ จะเท่ากับผลคูณในรูปใด}{/p} 

d. \[ \frac{5}{4} \times \frac{6}{5} = \boxed{\text{numerator}} \text{ ผลหารที่ได้ลงใน } \boxed{\text{denominator}} \text{ จะเท่ากับผลคูณในรูปใด}{/p} 

e. \[ \frac{5}{6} \times \frac{5}{4} = \boxed{\text{numerator}} \text{ ผลหารที่ได้ลงใน } \boxed{\text{denominator}} \text{ จะเท่ากับผลคูณในรูปใด}{/p} 

10. " parte de nuestra visita al centro de salud. EL: "

75 กิโลเมตรต่อวัน ทนที่ประมาณเหนือระดับความเข้มแข็ง

11 ชั่วโมงต่อวัน เท่ากับกิโลเมตรต่อวัน

832 กิโลเมตร ใช้เวลาเดินทาง

92.3 ลิตร

11 ชั่วโมงต่อวัน เท่ากับกิโลเมตรต่อวัน

ผลตอบที่ถูกต้อง นั่นคือเป็นในการหาค่าตอบ

a. 75 กม./ชม. 832 กม. น้าน 35.6 ลิตร
b. 832 กม. 11 ชม.
c. น้าน 92.3 ลิตร 832 กม.
d. 832 กม. 75 กม./ชม.
e. น้าน 92.3 ลิตร 11 ชม.
11. "จะเลือกเส้นหนึ่งجاว $3 \frac{1}{2}$ หน่อย ดังภาพดังเนื้อหานี้ๆ

30 ท่อน จะได้เส้นยาวท่อนละกี่นิ้ว?

นําความในจําลนวนนี้ไปเป็นประโยคดังกล่าวนี้อย่างไร

ก. $(3 \frac{1}{2} \times 30) + 12 = \boxed{}$

บ. $3 \frac{1}{2} + (30 + 12) = \boxed{}$

ข. $3 \frac{1}{2} \times 30 \times 12 = \boxed{}$

ค. $30 + (3 \frac{1}{2} \times 12) = \boxed{}$

ง. $(3 \frac{1}{2} \times 12) + 30 = \boxed{}$

12. จะเลือกเลขตรีสที่เหมาะสมแก่ความหมายของ $0 + 8 = \boxed{}$

ก. $0 + 8 = 0$ เนื่องจากจำนวนใดๆเมื่อไปหาร 0

ย่อมได้ผลหารเป็น 0

บ. $0 + 8$ ไม่สามารถหาหนัสด้วยหมายเลขได้ เนื่องจาก

การหารที่มีตัวตัวนั้น จึงไม่มีความหมาย

ข. $0 \div 0$ ไม่สามารถหาหนัสด้วยหมายเลขได้ เนื่องจาก

คู่ง่ายไม่มีตัว

ค. $0 \div 8 = 8$ เนื่องจาก คู่ง่ายไม่มีตัว

ง. $0 + 8$ ไม่สามารถหาคำตอบได้ เนื่องจากคู่ง่ายไม่ตัวอย่างมาก
13. ประโยคสมบัติเลขทศนิยมในบวกคณิตเลขด้วยหลักเกณฑ์การหารของ $\frac{1}{2} + \frac{3}{8}$

น. $\frac{1}{2} + \frac{3}{8} = \frac{1}{2} = \frac{1}{2} \times \frac{3}{8} = \frac{1}{2} \times \frac{8}{3}$

บ. $\frac{1}{2} + \frac{3}{8} = \frac{1}{2} + \frac{3}{8} = \frac{1 \times 3}{2 \times 8} = \frac{1}{2} \times \frac{8}{3}$

ค. $\frac{1}{2} + \frac{3}{8} = \frac{3}{2} + \frac{1}{8} = \frac{3 + 1}{2 + 8} = \frac{3}{16} = \frac{3}{2} \times \frac{1}{8} = \frac{1}{2} \times \frac{8}{3} = \frac{1}{2} \times \frac{8}{3}$

ง. $\frac{1}{2} + \frac{3}{8} = \frac{1}{2} + \frac{3}{8} = \frac{\frac{1}{2} \times \frac{8}{3}}{\frac{3}{8}} = \frac{1}{2} \times \frac{8}{3}$

จ. ไม่มีข้อได้บุก

14. ถ้า $7 + \frac{2}{3} = \square$ แล้ว ผลหารที่คิดอยู่ใน $\square$ จะเท่ากับผลดิบูใน $\square$

ในบวกได้

น. $7 \times \frac{2}{3} = \square$

บ. $7 \times \frac{3}{2} = \square$

ค. $\frac{1}{7} \times \frac{3}{2} = \square$

ง. $\frac{1}{2} \times \frac{3}{2} = \square$

จ. $\frac{7}{3} \times 2 = \square$
15. นัด $\frac{3}{8} + 5 = $ แล้ว ผลหารที่เดิมลงใน $\Box$ จะทำรันนั้นลงในข้อใด

ก. $\frac{8}{3} \times 5 = $  กร.

ข. $3 \times \frac{5}{8} = $  กร.

ค. $\frac{3}{8} \times 5 = $  กร.

ง. $\frac{8}{3} \times 5 = $  กร.

จ. $\frac{3}{8} \times \frac{1}{5} = $  กร.

16. นัด $\frac{2}{3} + \frac{3}{8} = $ แล้ว ผลหารที่เดิมลงใน $\Box$ จะทำรันนั้นลงในข้อใด $\Box$

ก. $\frac{2}{3} \times \frac{5}{8} = $  กร.

ข. $3 \times \frac{5}{8} = $  กร.

ค. $\frac{3}{8} \times 5 = $  กร.

ง. $\frac{8}{3} \times 5 = $  กร.

จ. $\frac{3}{5} \times \frac{8}{2} = $  กร.
ตอบที่ 3

17. ตัวตั้งเหล้าให้ลูกค้าจำนวน 14 ตัน ถ้าผลสำรับบรรดา ได้เกียรด 3 ตัน จะต้องบรรทุกทั้งหมดกี่เกียรตังจะหมด

ก. 4 เกียรตัน เศษ 2 ตัน

ข. 4 เกียรตัน

ค. $4 \frac{2}{3}$ เกียรตัน

ง. 5 เกียรตัน

จ. 42 เกียรตัน

18. เมื่อปีที่แล้ว บริษัทของน้ำมันเชื้อเพลิงจำนวน 5,204 ตัน ได้เงินรวม 1,533,662.28 บาท

บริษัทของน้ำมันเชื้อเพลิงเลือกจากประมาณขึ้นลงเท่าไร

ก. 100 บาท

ข. 200 บาท

ค. 300 บาท

ง. 400 บาท

จ. 500 บาท
19. จัดหาสิ่งแวดล้อมที่มีกิจวัตร 40 $\frac{5}{8}$ ขั่วโมง โดยทำงานวันละ 6 $\frac{1}{2}$ ขั่วโมง ต้องใช้เวลาทั้งวันจึงจะเสร็จ


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20. นี้ได้เรียงลำดับจากระหว่างที่มีค่าถ้ามีย่อมีข้อ โปรดจ่านวันที่มีค่ามาก


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</tbody>
</table>

21. ดาลินและคนละ นับถ่านออกจากจุดจรรยาบิลก 390 รอบ ใช้เวลา 24 วัน 6 ขั่วโมง 37 นาที ถ้าทำจรรยาบิลก 1 รอบ จะใช้เวลาโดยประมาณที่ขั่วโมง


<table>
<thead>
<tr>
<th>เลข</th>
<th>ขั่วโมง</th>
</tr>
</thead>
<tbody>
<tr>
<td>๑</td>
<td>$1\frac{1}{2}$ ชั่วโมง</td>
</tr>
<tr>
<td>๒</td>
<td>15 ชั่วโมง</td>
</tr>
<tr>
<td>๓</td>
<td>$2\frac{1}{2}$ ชั่วโมง</td>
</tr>
<tr>
<td>๔</td>
<td>25 ชั่วโมง</td>
</tr>
<tr>
<td>๕</td>
<td>$3\frac{1}{2}$ ชั่วโมง</td>
</tr>
</tbody>
</table>
22. ชายที่ขับรถระยะทาง 654 กิโลเมตร ใช้น้ำมันหมดใน 
\( \frac{3}{4} \) ถัง ถ้ามีน้ำมันเต็มถัง

\[ \frac{490.5}{872.0} \text{ กิโลเมตร} \]
\[ \frac{817.5}{523.2} \text{ กิโลเมตร} \]
\[ \frac{942.2}{523.2} \text{ กิโลเมตร} \]

23. อายุเกิ้นขับรถระยะทาง 1,178 ไมล์ ใช้น้ำยา 19 ช่วงไถง 34 นาที 47 วินาที

\[ \frac{40}{60} \text{ ไมล์/ช่วงไถง} \]
\[ \frac{60}{80} \text{ ไมล์/ช่วงไถง} \]
\[ \frac{80}{90} \text{ ไมล์/ช่วงไถง} \]
\[ \frac{90}{100} \text{ ไมล์/ช่วงไถง} \]

24. เนื้อเดิม 1 ชิ้นทำจากเนื้อลดหนัก \( \frac{5}{8} \) กิโลกรัม ถ้าใช้เนื้อลดหนัก 20

กิโลกรัม จะได้เนื้อเดิมกี่ชิ้น

\[ \frac{6\frac{1}{4}}{64} \text{ ชิ้น} \]
\[ \frac{1}{64} \text{ ชิ้น} \]
\[ 64 \text{ ชิ้น} \]
\[ 6 \text{ ชิ้น} \]
\[ 24 \text{ ชิ้น} \]
25. ข้อใดเรียงลำดับจากจำนวนที่มีตัวมาก ไปหานั้นที่มีตัวน้อย

\[
\begin{align*}
\text{ก.} & \quad \frac{5}{32} \cdot \frac{11}{16} \cdot \frac{7}{8} \cdot \frac{3}{4} \\
\text{ข.} & \quad \frac{11}{32} \cdot \frac{7}{8} \cdot \frac{5}{32} \cdot \frac{3}{4} \\
\text{ค.} & \quad \frac{7}{8} \cdot \frac{3}{16} \cdot \frac{11}{8} \cdot \frac{5}{32} \\
\text{ง.} & \quad \frac{3}{4} \cdot \frac{7}{8} \cdot \frac{11}{16} \cdot \frac{5}{32} \\
\text{จ.} & \quad \frac{3}{4} \cdot \frac{5}{32} \cdot \frac{7}{8} \cdot \frac{11}{16}
\end{align*}
\]

26. น้ำวินปั้นจักรยานจากชุดมีไปเชิงรายเบี่ยงระยะทาง 1,438 กิโลเมตร ใช้เวลา 18 วัน น้ำวินเดินทางเลื่อนปริมาณวันละ เท่าไร

\[
\begin{align*}
\text{ก.} & \quad 20 \text{ กิโลเมตร} \\
\text{ข.} & \quad 30 \text{ กิโลเมตร} \\
\text{ค.} & \quad 40 \text{ กิโลเมตร} \\
\text{ง.} & \quad 50 \text{ กิโลเมตร} \\
\text{จ.} & \quad 60 \text{ กิโลเมตร}
\end{align*}
\]
27. ในการวิสุทธิ์การพิจารณาจำนวนกระดาษด้วยวิธีเปลี่ยน
เครื่องหมายการเป็นตูกและการกลับตัวแต่นั้นเป็นตัวล่าง
ต้องใช้วิธีไหนบ้าง

ก. กำหนดตัวเลขที่มีภาษาไทยของอย่างน้อย 3 จำนวน
ข. กำหนดตัวล่างที่ตัดแยกให้ 1 ตัวอย่าง
ค. แสดงรายการวิชานิยมพิจารณาจำนวนกระดาษตามนั้น
ง. ปัจจุบันโดยใช้การลบออกครั้งละเท่ากัน
จ. เปรียบเทียบกับการพิจารณาจำนวนนั้น

28. เมื่อประโยคดังกล่าว $\frac{1}{2} \times \frac{3}{4} = \frac{2}{3}$ เบียนริง

ถ้าจำนวน $\frac{3}{4}$ มีค่าเท่ากัน

แต่ตัวที่ $\frac{1}{2}$ มีค่าที่น้อยกว่า

จำนวน $\frac{2}{3}$ จะมีค่าเท่ากัน

ก. เท่ากัน
ข. ลดลง
d. คงที่
ง. ไม่สามารถตอบได้ เนื่องจากค่าเป็นตัวตรึงอยู่แล้ว
ej. ไม่มีตัวเลขตัวเลขไม่มีตารางค่า
29. ในประโยคลังสุจน์การหารใดๆ ถ้าผลหารมีตัวเลขเดี่ยว ตัวเลขใดที่เป็นตัวตัวนั้นตัวเลขใดจะมีตัวตัวยิ่งที่ใด
ก. เท่ากับบ้าน
ข. กลับ
ค. คงที่
ง. ไม่สามารถบอกได้ เพราะโจทย์ไม่กำหนดตัวให้
จ. ไม่มีบังคับให้ เพราะไม่มีปัญหาที่ค่า

30. นั่นคือการหาค่าสุ่มนั้นที่กับกฎการหาร จากวัตถุต่างๆ โดยการ
เปรียบเทียบระหว่างหารเป็นตัว แล้วกลับด้านตัวเป็นตัวว่า
ก. \[ \frac{a+c}{b+d} = \frac{a \times d}{b \times c} \]
ข. \[ \frac{a+c}{b+d} = \frac{a}{c} \]

ค. \[ \frac{a+c}{b+d} = \frac{c}{d} = \frac{a \times d}{b \times c} = \frac{a \times d}{b \times a} = \frac{a \times d}{b} = \frac{b \times c}{a \times d} \]

ง. \[ \frac{a+c}{b+d} = \frac{a}{b} \times \frac{d}{c} = \frac{a \times d}{b \times c} = \frac{a \times d}{b \times d} = \frac{a \times d}{b \times c} \]

จ. \[ \frac{a+c}{b+d} = \frac{a}{b} \times \frac{c}{d} = \frac{a \times c}{b \times d} = \frac{a \times d}{b \times c} \]
31. "9.9356 หารด้วย 4.21 เท่ากับ 2.36" จากนั้นว่า
ถ้ากล่าวว่า ถ้าทั้งด้านข่าวดังกล่าว บนกระดาษมีดังที่ ผลหารจะมีค่าอย่างไร

ก. เนิ่นเอ็น

บ. ผลAllocate

ค. ดังกล่า

ง. ไม่สามารถบอกได้ เข้าเดินที่เปลี่ยนแปลงไม่ได้

จ. ไม่มีอะไรสุดๆ เข้าไม่มีตัวคัดองการถ้านาน

32. นั่นต้องเป็นการสุ่มสูงนี้เกี่ยวกับการตรวจจับวิเคราะห์โดยเปลี่ยน
dreio ออกมาการเบื้องต้น และวัสดุกลับที่ดับเบิ้ลในด้าน

ก. \( \frac{x + z}{y + w} = \frac{x \cdot w}{y \cdot z} \)

บ. \( \frac{x + y}{z} = \frac{x}{y} \)

ค. \( \frac{x + z}{w} = \frac{y^{z}}{w} = \frac{x \cdot z}{w} = \frac{x \cdot w}{y \cdot z} = \frac{x \cdot w}{y \cdot z} = \frac{z}{w} \)

ง. \( \frac{x + z}{y + w} = \frac{x \cdot z}{y \cdot w} = \frac{x \cdot w}{y \cdot z} = \frac{y \cdot z}{x \cdot w} = \frac{y \cdot z}{x \cdot w} = \frac{x}{z} \)

จ. \( \frac{x + y}{z} = \frac{x}{z} \)
APPENDIX W

Elementary Curriculum in Thailand

Elementary education in Thailand is formed into a single unit taking 6 years to complete. Compulsory education is that which requires every boy and girl to attend school up to grade 6 or to the age of 15 in case of repetition of some grades.

The program aims at providing basic knowledge and skills, as well as maintaining literacy and computational abilities. It provides practical experiences leading to the world of work and citizenship under the democratic system, with the Monarch as the Head of State.

The elementary school curriculum is formulated under the following policies:
1. It is meant for all children.
2. It provides functional experiences within a terminal program.
3. It builds national unity, and consequently, consists of certain common components. It encourages diversification and validation to suit local needs and situations.

The learning experiences are classified into four main areas:
1. Tool subjects, comprised of the Thai language and mathematics.
2. Life experiences, involving the problems solving process, and the various aspects of human societal needs and problem for the purpose of survival and leading a good life.
3. Character development, dealing with experiences conducive to development and habit formation.
4. Work-oriented experiences, involving practical work and establishment of a vocational foundation.

The educational program consists of a total number of 75 periods per week, with a duration of 20 minutes per period. The total duration of one school day is 6 hours, usually lasting from 9:00 a.m. to 3:00 p.m., with a 1-hour recess period between noon and 1:00 p.m. The schools are required to be open for at least 200 days per year. It should be noted that students in grades 5 and 6 are required to study English or work education as an elective subject for another 5 hours per week.

This curriculum provides not only content and concepts to be taught, but also detailed behavioral objectives. Teaching and learning are centered around children’s abilities in terms of thinking, doing, and feeling. Evaluation of student learning depends very much on internal assessment by the school. The end-of-school-year examination at grade 6 by external authority district educational officers still remains.
APPENDIX X

Teachers’ College in Thailand

Higher education in Thailand is diversified in terms of content of study. The curriculum used in each institution may differ from one to another, even though it is in the same field of study. Jurisdictionally, the Office of State Universities approves the curriculum of all higher education institutions, except for special training programs, such as those offered by teachers’ colleges. It is the institution itself that initiates a new curriculum and asks for an evaluation and approval from the Office of National Education. The teacher profession in Thailand is restricted and teachers are never allowed to teach in private institutions.

The Teacher Education Department, represented by 36 teachers’ colleges, offers both preservice and inservice training. Both types of training give learners a wide variety of programs of specialization.

Other in-service training programs aim at teachers in elementary and secondary schools. There is a joint-project between the Teacher Education Department and the Office of the National Primary Education Commission to provide in-service training to all elementary teachers for a period of 1 week once every 5 years. This project started in 1988 and 72,000 elementary school teachers have so far been trained and updated in their content subject areas and in teaching methodology. Short-term training in mathematics and science is offered annually to supervisors and elementary and secondary school teachers throughout the country at every Science and Technology Teachers Servicing Center, located at all teachers’ colleges.

Teachers’ college curricula are designed in accordance with the philosophy of higher educational institutions and the necessary academic standards for each professional subject area. The curricula aim is to develop good citizenship, and equip students with knowledge, skills and ability as well as techniques for their future career. The curricula also help teachers develop good attitudes toward their specialized subject area (Teacher Education Department, Ministry of Education, Thailand, 1993). At the teachers’ colleges, courses are offered at two levels—namely, Associate Degree level, following a 2-year plan, and Bachelor’s Degree level, which follows a 4-year plan. Curricula offered at the Associate Degree level aim to train personnel with semi-professional and technical skills to meet the needs of the local community. The curricula are designed in accordance with the National Economic and Social Development Plan, incorporating high flexibility, so that learning programs can be readily adapted to changing conditions. Curricula offered at the Bachelor’s Degree level aim to train learners in different subject areas of specialization in accordance with the Higher Education Development Plan, aiming for academic improvement and excellence, as well as meeting the needs of the locality and the community. The curricula plan encompasses the teaching profession
for both the elementary school level (Grades 1 to 6) and the secondary school level (Grades 7 to 12).

**Principles of Teacher Education Curricula**

Teacher Education Curricula in Thai teachers' colleges are designed to equip learners with the following qualifications:

1. Subject matter competency, teaching techniques and acquiring the qualities of a good teacher.
2. Teachers' responsibilities and morale.
3. Experience and activities by which to focus the balance between theory and practice.
4. Flexibility to the needs of employers as well as keeping standards, especially in terms of professional experience training.

**Objectives of Teacher Education Curricula**

Objectives aimed at learners, after the completion of the program of study, are as follows:

1. Good attitude and faith in the teaching profession, acquiring required value judgment, good morale and ethics, and enthusiasm for self-development.
2. Well-informed in both subject matter and teaching techniques.
3. Creativity, skills and ability at problem solving.
4. Physically and mentally healthy (both personally and publicly).
5. Consideration of social development and public welfare.
6. Acquiring a democratic mind in accordance with the Constitution, which comprises three entrees: Nation, Religion, and Monarchy.
7. Preserving national and cultural identity to create an awareness of good citizenship.
APPENDIX Y

Map of Data Collection Area

The 12 education regions