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ABSTRACT

This study attempted to ascertain if the elements perceived in the physics concepts of mass and weight differed for students of different cultural backgrounds. Responses of two matched groups of 19 students each, one from the United States and the other from Taiwan, were studied; students were given word association tests and a physics problem set and were asked to rank the level of importance of conceptual elements. Results of the analysis of characteristics of conceptual elements showed no significant differences for students within the same culture. The understandings of the concepts of weight and mass by the two groups were comparable, and the importance of problem-related conceptual elements was perceived similarly by both groups. Significant differences between groups were found for the word association tests, with Taiwan students associating more physical science and problem-related conceptual elements with the stimulus words "mass" and "weight." Findings also showed that Taiwan students were more influenced by the problem set, were less divergent in their responses to the stimulus work "mass," and showed more memorization than did the students from the United States. (Author/DT)

A STUDY OF CONCEPTUAL ELEMENTS INVOLVED IN TWO PHYSICS TERMS FOR STUDENTS OF DIFFERENT CULTURAL BACKGROUNDS

By

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The Ohio State University, 1974

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The general problem of this study was to ascertain whether or not the elements perceived in the physics concepts of mass and weight differed for students of different cultural backgrounds. The specific problems were:

1. What characteristics of conceptual elements are specific to a sample group of specific cultural background?
2. What characteristics of conceptual elements correlate to student performance on a test?
3. What characteristics of a physical science conceptual scheme are specific to a sample group of specified cultural background?

The four aspects on which data were collected were: those concerning personal characteristics of the sample students; the elements involved in two physics concepts, mass and weight, as perceived by the student on word association tests; the physics problem set used to focus the student's perceptions of conceptual elements; and the level of importance at which the student ranked a conceptual element. The number of times a conceptual element was used by the student to solve the problem set was determined on the basis of his perceived conceptual elements and his answers to the problem set.

Data utilized were resolved into two categories: matching measures and test variables. Matching measures included sex, California Short-form Test of Mental Maturity score, reading ability score, and average score in science (biology and chemistry). Test variables included score on the problem set; number of conceptual elements for each of nine categories as elucidated by the student; importance index of conceptual elements; and number of correct and incorrect uses of conceptual elements in the solution of the problem set.

Matching data were found to serve satisfactorily for the selection of two groups of matched students consisting of nineteen students each, from two cultures, Worthington, Ohio, and Taiwan. Frequency distributions with respect to the students' association behaviors were comparable for both Worthington and Taiwan groups.

Analysis of characteristics of conceptual elements showed that no significant difference was found for students within the same culture. The understanding of the concepts of mass and weight by Worthington and Taiwan student groups was comparable, and the importance of problem-related conceptual elements was perceived similarly by both student groups. Cluster analysis and hierarchical presentation showed that both Worthington and Taiwan student groups used many similar conceptual elements in the solution of the problem set.

However, Taiwan students associated more physical science and problem-related conceptual elements with the stimulus words, mass and weight, than did Worthington students. Differences were significant at the 0.05 level. The number of additional conceptual elements was significantly higher ($\alpha = 0.01$) for Taiwan students than for Worthington students. More than one third of forty-five problem-nonrelated conceptual elements perceived in mass by Worthington student group related to religion, but only one out of thirty problem-nonrelated conceptual elements perceived in mass by Taiwan student group related to "quality," an implied meaning of mass in Chinese. Taiwan students used more high level physical terms (e.g., relativity, field) in solving the problem set than did Worthington students. More terms relating to body image were associated with weight by the Worthington student group than by the Taiwan student group.

Taiwan students were more influenced by the problem set and appeared less divergent in thinking in response to the stimulus word "mass" than were Worthington students. Taiwan students showed more memorization than their counterparts in Worthington. Cultural effects on perceptions of physics concepts resulted from varying attitudes toward tests, learning processes, human relationships, and societal economic achievement.

Recommendations are made for changes in physics teaching in Taiwan, and suggestions are made for further research.

Stanley L. Helgeson

A STUDY OF CONCEPTUAL ELEMENTS INVOLVED IN TWO PHYSICS TERMS FOR STUDENTS OF DIFFERENT CULTURAL BACKGROUNDS

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

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CHAPTER I

INTRODUCTION

The Problem

In the field of science education, the emphasis of almost all curriculum projects has been on concept learning. The usual way of teaching concepts is by means of the process of grouping similar situations and experiences in which the basis of commonality is used to recognize additional members.

The instructional material in science curricula is generally designed along the same line. Subject matter concepts are presented from a lower degree of abstraction to a higher degree and form a specified conceptual scheme. The instruction usually repeats the procedures of inducing the student's memory of old experiences and inculcating additional information.

There is general agreement that science is a schematically organized enterprise. However, there is no specific agreement on how science should be taught to help a student perceive commonality and generalize acquired knowledge.

The focus of this study was to assess students' conceptual commonality by analyzing two concepts in physics, and to examine the nature of the schemes involved in students' cognitive generalization of the concepts to practical problems. Special attention was paid to the students' own elucidation of elements involved in these two physics concepts.

The two selected physics concepts were mass and weight. Each concept was analyzed into its elements through the students' responses to two stimulus words: mass and weight. The conceptual scheme was studied by assessing the students' performances on a problem set in terms of their own elucidated elements.

Another area of concern involved the differences of students' perceptions of concepts with varying cultural backgrounds. The student subjects used in this study were selected from two places: Worthington, Ohio, the United States, and Taiwan, the Republic of China. All the subjects were senior high school students taking the Physical Science Study Committee (PSSC) physics course.

Need for the Study

The assessment of the conceptual elements and schemes perceived by the students themselves in their recognition of physics concepts was considered desirable at this time because of the drastically decreasing interests of U.S. secondary school students in physics. The percentage of high school students enrolled in physics decreased from 25.7 percent in 1948 to 20.5 percent in 1964 (Simon and Grant, 1970). Criticism has focused on college teachers' neglect of the nature of the students' learning processes. More emphasis should be placed on eliciting the students' own perceptions of learned concepts rather than on scientists' logical thinking about concepts. Bruner stated:

> Education must begin, as Dewey concluded his first article of belief, 'with a psychological insight into the child's capacities, interests, habits,' . . . . It is just as mistaken to sacrifice the adult to the child as to sacrifice the child to the adult (1966, p. 117).

Individual differences have been the main concern of educators for a long period of time. A few research studies have been conducted to clarify individual differences in conceptual activities. It seemed necessary to initiate a study of these types of individual differences to offset the undermining effect of the statement made by Jensen.

> To contemplate the problems of studying individual differences (IDs) even in relatively 'simple' forms of learning, such as conditioning, motor learning, or rote learning, can be an unnerving enterprise. To have to think about IDs in conceptual learning is quite overwhelming! (1965, p. 139)

There has been much interest in concept learning for some time. However, there have been no definite resolutions in the research of concept learning. Voelker made a strong statement when he said: "There is no research pattern for study of classificatory concepts, relational concepts, or theoretical concepts. Thus, the nature-of-the-concept variable is not controlled" (1973, p. 4).

In summary, it may be said that the understanding of concept learning has been an elusive objective in the education community as a whole. The study of the effects of differences in cultural backgrounds on the perception of elements involved in two physics concepts is the starting point for understanding the process involved in learning a specific conceptual task. This study can be utilized by the textbook writer as a basis for the revision of instructional materials for a specified student group, and by the physics teacher as a criterion for making special efforts in the explanation of certain conceptual elements in mass and weight. It can also serve as a basis for assessing strengths and weaknesses of related instructional material for those educators considering its possibilities for selection in their teaching.

Problems and Sub-Problems

The general problem of this study was to ascertain whether the elements perceived in the concepts of mass and weight differ for students of different cultural backgrounds. The specific problems were:

1. What characteristics of conceptual elements are specific to a sample group of specific cultural background?
2. What characteristics of conceptual elements correlate to student performance on a test?
3. What characteristics of a physical science conceptual scheme are specific to a sample group of specified cultural background?

The following hypotheses were organized for the analysis and interpretation of the data.

Hypotheses

The null hypotheses tested by the investigator were organized according to the first two problems as stated above. The .05 level of statistical significance was assumed for statements of significant findings unless specified otherwise.

Hypotheses Concerning Cultural Background

1.1 There is no significant difference between the sample groups of varying cultural backgrounds in terms of the total number of conceptual elements elucidated by the students.

1.2 There is no significant difference between the sample groups of varying cultural backgrounds in terms of the number of problem-related conceptual elements elucidated by the students.

1.3 There is no significant difference between the sample groups of varying cultural backgrounds in terms of the number of problem-nonrelated conceptual elements elucidated by the students.

1.4 There is no significant difference between the sample groups of varying cultural backgrounds in terms of the number of physical science conceptual elements elucidated by the students.

1.5 There is no significant difference between the sample groups of varying cultural backgrounds in terms of the number of everyday conceptual elements elucidated by the students.

1.6 There is no significant difference between the sample groups of varying cultural backgrounds in terms of the number of additional conceptual elements elucidated by the students.

1.7 There is no significant difference between the sample groups of varying cultural backgrounds in terms of the number of deleted conceptual elements elucidated by the students.

1.8 There is no significant difference between the sample groups of varying cultural backgrounds in terms of the scale of importance of problem-related conceptual elements elucidated by the students.

1.9 There is no significant difference between the sample groups of varying cultural backgrounds in terms of the scale of importance of problem-nonrelated conceptual elements elucidated by the students.

1.10 There is no significant difference between the sample groups of varying cultural backgrounds in terms of the number of overlapping conceptual elements elucidated by the students.

1.11 There is no significant difference between the sample groups of varying cultural backgrounds in terms of the number of exclusive conceptual elements elucidated by the students.

1.12 There is no significant difference between the sample groups of varying cultural backgrounds in terms of the number of correct uses of conceptual elements in the solution of problems.

1.13 There is no significant difference between the sample groups of varying cultural backgrounds in terms of the number of incorrect uses of conceptual elements in the solution of problems.

Hypotheses Concerning Student Achievement

2.1 There is no significant difference between the high- and low-achieving sample subgroups in terms of the overall number of conceptual elements elucidated by the students.

2.2 There is no significant difference between the high- and low-achieving sample subgroups in terms of the number of problem-related conceptual elements elucidated by the students.

2.3 There is no significant difference between the high- and low-achieving sample subgroups in terms of the number of problem-nonrelated conceptual elements elucidated by the students.

2.4 There is no significant difference between the high- and low-achieving sample subgroups in terms of the number of physical science conceptual elements elucidated by the students.

2.5 There is no significant difference between the high- and low-achieving sample subgroups in terms of the number of everyday conceptual elements elucidated by the students.

2.6 There is no significant difference between the high- and low-achieving sample subgroups in terms of the number of additional conceptual elements elucidated by the students.

2.7 There is no significant difference between the high- and low-achieving sample subgroups in terms of the number of deleted conceptual elements elucidated by the students.

2.8 There is no significant difference between the high- and low-achieving sample subgroups in terms of the scale of importance of problem-related conceptual elements elucidated by the students.

2.9 There is no significant difference between the high- and low-achieving sample subgroups in terms of the scale of importance of problem-nonrelated conceptual elements elucidated by the students.

2.10 There is no significant difference between the sample subgroups of high and low achievement in terms of the number of overlapping conceptual elements elucidated by the students.

2.11 There is no significant difference between the sample subgroups of high and low achievement in terms of the number of exclusive conceptual elements elucidated by the students.

2.12 There is no significant difference between the sample subgroups of high and low achievement in terms of the number of correct uses of conceptual elements in the solution of problems.

2.13 There is no significant difference between the sample subgroups of high and low achievement in terms of the number of incorrect uses of conceptual elements in the solution of problems.

Hypotheses Concerning Correlation Between Conceptual Elements and Student Achievement

3.1 There is no significant correlation between the student's achievement score and his number of correct uses of conceptual elements in the solution of the problem set.

3.2 There is no significant correlation between the student's achievement score and his number of incorrect uses of conceptual elements in the solution of the problem set.

3.3 The difference in number of correct and incorrect uses of conceptual elements in the solution of the problem set does not correlate significantly to the student's achievement score.

Hypotheses Concerning Cluster Analyses

The following bi-factor analyses were made according to the third problem as stated above. Cluster analysis of conceptual elements was performed using the B-coefficient calculation (Harman, 1967).

4.1 There is no conceptual element cluster for the subgroup of Worthington high-achieving students.

4.2 There is no conceptual element cluster for the subgroup of Worthington low-achieving students.

4.3 There is no conceptual element cluster for the subgroup of Taiwan high-achieving students.

4.4 There is no conceptual element cluster for the subgroup of Taiwan low-achieving students.

4.5 There is no conceptual element cluster for the group of Worthington students as a whole.

4.6 There is no conceptual element cluster for the group of Taiwan students as a whole.

Definitions

Clarification of certain terms used by this investigator is necessary for an adequate interpretation of the materials which follow. Terms are defined and explained at this point. These terms are defined specifically for the purpose of this study and may or may not generally be defined in this same manner.

Basic Definitions

Achievement score - the number of correctly solved mass-weight problems on the instrument prepared for this study.

Conceptual element - an object, event, or attribute of the object or event perceived by a student in response to a physical science stimulus concept (Klausmeier, et al., 1969).

High- or low-achieving student subgroups - students assigned to a subgroup based on a median score on a problem set.

Scale of importance - a test or a numerical ranking index assigned to a conceptual element according to the student judgment of the element's importance, with one rank increment equaling the reciprocal of the total number of elements perceived by a student.

Definitions Concerning Conceptual Elements

Additional conceptual element - an element added by a student after working on the problem set.

Conceptual element cluster - highly correlated conceptual elements (three or more) determined by B-coefficient analysis.

Deleted conceptual element - an element eliminated by a student after working on the problem set.

Everyday conceptual element - an element pertaining to everyday life.

Exclusive conceptual element - an element appearing as a response only to one of the two stimulus words.

Overlapping conceptual element - an element appearing as a response to both stimulus words, mass and weight.

Problem-nonrelated conceptual element - an element described by subjects as not being used in solving a problem.

Problem-related conceptual element - an element described by subjects as being used in solving a problem.

Delimitations of the Study

Delimitation factors were as follows:

1. The human subjects in Worthington were selected from the high school which agreed to allocate time enough for the investigator to administer two word association tests and a problem set.
2. Eastern and Western cultures were represented by students in Taiwan, R.O.C., and in Worthington, Ohio, U.S.A.
3. The period of time encompassed by this study was the 1973-1974 school year.

4. Only two physics concepts (mass, weight) were selected for investigation.
5. This study was not concerned with students' operational difficulties with the problem set, such as mathematical skills.
6. The subjects used were limited to those students taking the PSSC course.
7. Diversity of instructional modes in teaching physics in Worthington and in Taiwan was not analyzed.
8. Content differences in the offering of the PSSC course between the United States and the Republic of China were not taken into consideration in the study.
9. Differences resulting from the required and elective natures of the PSSC course offered in the two places were not considered in the study.
10. Important cognitive and noncognitive factors influencing students' conceptualization in physics learning, such as school equipment and facilities, the students' parental social status, the students' creativity and attitudes toward science and their academic backgrounds other than in biology and chemistry, local language styles, academic standards imposed on students' educational objectives, teacher characteristics, individuals' emotional status, classroom organization, and schooling systems were not analyzed.
11. The conditioning effects of the joint use of the mass-weight concept in the tests on the association behaviors of the students were not considered in the study.

Limitations of the Study

Based on the research design used and the above delimitations, the following limitations exist.

1. Administration of the tests to the sample in Taiwan by individuals other than this investigator may have influenced results.
2. The subjects tested included twenty-six students in Worthington and 358 students in Taiwan. The data analysis in terms of cultural differences was limited to two groups of subjects who matched each other on the basis of their average scores in biology and chemistry, mental maturity and reading ability scores, and sex.
3. Validity of the dichotomization procedures was limited by the reliability of the problem set.
4. Findings can be generalized beyond the sample used in the study only with great caution, due to the limitations of the samples involved.

Assumptions

The following assumptions were made in the study.

1. The word association test with a preset time limitation was assumed to be an appropriate instrument for a student to elucidate honestly and exhaustively all the elements involved in a concept.
2. A paper and pencil instrument intended to measure students' ability to use the perceived conceptual elements to solve problems was assumed to be devisable.
3. The teachers of the PSSC course in Taiwan were assumed to have the education and experience to administer properly the tests used in

the study.

4. Students' achievement scores in biology and chemistry were assumed to be a valid indicator of their understanding of science.

5. The cumulative folders were assumed to be valid and used to yield the intelligence quotients and reading ability and science scores for the students in Worthington.

Overview of the Study

The study was concerned with the effects of differences in cultural backgrounds on the perception of conceptual elements involved in two physics concepts. The period of time involved was the 1973-74 school year. The sample subjects consisted of students in Worthington High School, Worthington, a suburb of Columbus, Ohio, and students in diverse parts of Taiwan. Both groups of students were enrolled in the PSSC course when they participated in the study, and were dichotomized according to their achievement scores on the problem set.

The selected group in Taiwan matched the group in Worthington on the basis of their scores in the school cumulative folders and scores on the mental maturity test. The cumulative folders were used to yield scores in biology and chemistry, scores in reading ability, and eventually intelligence quotients if the administration of a mental maturity test was impossible because of time limitations.

Summary and Overview of Chapters to Follow

This chapter presented an introduction to the problem to be investigated and need for the study. The general problem was stated and sub-problem hypotheses were described concerning subjects' cultural backgrounds and problem-solving achievements. Terms were then defined; delimitations, limitations, and assumptions stated; and an overview of the study presented.

Chapter II presents an overview of literature pertaining to abstraction versus concept formation, behaviorism and conception, developmental studies of concepts, concept formation and attainment, conceptual research in physics teaching, word association behaviors, cultural background factors, and integrated functional studies of concept attainment.

Chapter III contains the design of the study. The selection and classification of the subject sample, the pilot study, analysis of the two PSSC concepts, development and evaluation of the test used, and data collection and analysis are discussed.

Chapter IV presents the findings about conceptual elements, sample characteristics, and variances of achievements on the problem set used and of the number of uses of word associations. Analyses of hypotheses and conceptual element clusters in terms of sample characteristics are the main portion of this chapter.

Chapter V presents a summary of the findings, conclusions, and recommendations for physics teaching and further studies.

CHAPTER II

REVIEW OF RELATED LITERATURE

This chapter has two sections. The first section examines diverse schools of philosophy of conceptual studies and differences in concept formation and attainment. The second section explores conceptual studies in the teaching of physics, including the word association technique, cultural factors, and integrated functional approaches to the research of concept attainment.

Conceptual Studies: Formation vs Attainment of Concepts

Abstraction and Conception

> By abstraction we generally mean the procedure by which certain constituent parts are eliminated from a compound idea or from several such ideas and what remains is retained as the elements of a concept. Moreover, abstraction is the principal means of forming general concepts (Wundt, 1894, p. 10).

Historically, questions of concept have not been questions of concreteness, but of abstraction. Material objects must be converted into abstract ideas prior to being combined with other ideas, which are in the form of events and attributes of objects or events, to create new ideas in the cognitive domain. As a process of mental separation from particular instances or material objects, conception is, more or less, synonymous with discrimination and generalization through perception. In this sense, Aristotle and Berkeley deserve to be named as the first two pioneers in the field. Aristotle defined abstraction as disregarding the particulars in order to extract what is in common, and Berkeley consistently denied the possibility of abstract ideas under the prerequisite condition for existence (Pikas, 1966).

In 1893, Wundt analyzed "singular concepts" on the basis of the idea of a "falling stone" and pointed out that a concept was a "logical result." From this, singular concepts were transformed into general concepts "as soon as the judgme: , from whose organizing activity concepts emanate, gives expression to a number of related experiences" (Pikas, 1966, p. 11). Wundt's contemporaries agreed on this interpretation, some defining a concept as a habit and an organized memory (Ribot, 1897).

In the first two decades of this century, important roles were played by German philosopher-psychologists. The term "abstraction" was referred to as a purposeful selection or generalization which could be revealed through introspective statements. The product of such processes was denoted as a concept.

In summary, concepts were akin to abstraction by which closely related experiences were pooled to develop and assimilate new knowledge.

Behaviorism and Conception

Between the period from the 1920's to the 1950's, psychological theories usually went under the name of motor theories and justified the general qualities of a concept by eliciting reactions from the subjects in experiments. The ambiguity between abstraction and concept formation, encountered in the previous German discussions, was not substantially decreased through the efforts made in this period, but a decline in the use of the term "abstraction" was apparent.

Hull (1920) applied motor and stimulus-response theories in the sphere of abstraction and concept formation. He was the first researcher who studied concepts by means of observed behaviors. In his experiments, identical elements were sorted from different concepts. Gengerelli (1929) later identified opposing elements in addition to common elements, and Smoke (1932) argued that the verbalized relations which constituted concepts gave a much truer picture of the nature of the concepts than did the identical elements.

Beginning with Gelb and Goldstein (1920), many clinical psychologists took part in the study of concepts. Previous contradictions, such as abstractness versus concreteness, remained unsolved, and some study groups fell into the line of thought derived from Gestaltism, whereas others held associationistic views.

Heidbreder (1948) worked on the order of certain types of concepts with emphasis placed on ease of concept formation. In her work, concept formation and concept attainment seemed to be divorced from each other, and learning effects and the conditions of stimulus variations were dealt with carefully.

Behavioristic psychologists also concentrated on studying the effects on the conceptual processes of manipulating three classes of variables: stimulation, motivation, and reinforcement. Subjects in experiments were mostly college students and were treated to acquire an artificial concept in contrast to the Piagetian type of study.

Influences of these works were marked, leading to the emergence of many new ideas in the field. To Price (1953), a concept was defined as a recognitional capacity, and to Vinacke (1954), it was referred to as a cognitive organization system which brought pertinent past experience to bear on a present object or situation.

Questions of concept in the behavioristic theory were concerned with the uses of conceptual structure and with the tests, criteria, or principles by which these uses were determined. For example, Mednick (1957) and Arnhoff (1959) studied the relationship of their subjects' manifest anxiety scores to mediated or stimulus generalization; Hunt and Hovland (1960) examined how frequently their subjects chose each of three concept types as their initial basis for stating instances; and Bourne (1963) investigated the long-term effects of misinformative feedback upon performance in a concept identification problem.

In summary, a concept was regarded as a guiding force, a dynamic process for scanning perceptional data in the light of past experience. The viewpoint of the behavioristic psychologists is in agreement with the little that neurophysiology has so far been able to tell us about the functioning of the cognitive process.

Developmental Studies

Beginning with developmental psychologists' work, children have been used as experimental subjects. Many special contributions were made to the development of stage divisions which were subject to individual differences.

Russell (1956) stated the presence of the following stages: the presymbolic stage, the stage of preverbal symbolic behavior, the stage of implicit general ideas, and the stage of explicit generalization.

Piaget, another important researcher who has primarily concentrated on the accumulation of rich naturalistic observations concerning the cognitive life of children, indicated the presence of the sensorimotor period, the period of preoperational thought, the period of concrete operations, and the period of formal operations.

As an interpreter of Piaget's work, Bruner (1956) initiated, with his coworkers, the experimental work on the process underlying conceptualization. With the theoretical accounts originally offered by the mediation theory advocates (Osgood, 1956), Bruner used a set of eighty-one cards containing figures which could be categorized in many different ways and asked the subjects to form categories which were conjunctive, disjunctive, or relational. Emphasis was placed on the focusing and scanning strategies used by the subjects in attaining their concepts.

The merits of Bruner's work were obvious. Previous investigations had succeeded in giving a very general picture of the type of behavior which subjects exhibited in the concept attainment task, and also, of the sort of conditions which appeared to play a part. Bruner's work was a starting point for studying the content of the subject's thinking.

Flavell and Draguns (1958), on the basis of the theory that the series of events occurred in the course of a single, brief conceptual or perceptual act, used eighty-four university undergraduates as subjects to study a microdevelopmental pattern in concept formation. A word association test served to elucidate subjects' covert word responses which were less logical and more paleological in nature. However, in their research results, "microgenetically mature and immature" associations were not significantly different among the differently instructed subject groups.

The experimental work of D. M. Johnson (1961) on conceptual processes was concerned with "functional units which were larger than single responses but smaller than the whole problem-solving episode. He divided the conceptual process in two parts: the preparation part and the solution part, in the design of his experiment. The subjects in his experiment were given control of the switch from the preparation part to the solution part, by means of a serial exposure box. This enabled observations of the length of time spent on each part and the number of switches back and forth found necessary. As a conclusion, when preparation favored one dimension, the solution part was slanted toward the same direction.

Since 1955, the work of Piaget and his coworkers has become the focus of the attention of researchers dealing with the development of the concept of space, time, velocity, equilibrium, and conservation in children. Many research studies were completed, and inconsistencies emerged. For example, in comparing Piaget's experiment with the findings of Lovell's (1959) replicated experiment, the subjects tested by Lovell performed less well than those reported by Piaget. No indication of details of the socio-economic and cultural pattern background or intelligence of subjects in the Geneva study was described as the source of the difference.

In summary, concept attainment became a core of research studies in cases where the teaching-learning process was concerned. In addition to the two categories of research into which experiments on the effects of variables on task complexity (Bourne and Haygood, 1960) and experiments on the relationship of mediational processes to concept attainment (Kendler and Kendler, 1962) were classified, Bruner's type of research studies focusing on the informational processing in concept attainment emerged as a third category. Attempts to distinguish differences in subjects' concept formation are becoming more frequent, some replicating the experiments of others with a feature that no special treatments were given to the subjects in their experiments.

Concept Formation and Attainment

Vinacke differentiated the genetic aspects of concept formation from the problem-solving aspects by saying:

> This amounts, on the one hand, to a study of the origins of concepts in the learning of the infant and child and, on the other hand, to analysis of how the adult reorganizes his conceptual repertory and uses it in dealing with the external world (1952, p. 98).

The limitations Vinacke imposed on the learning of the infant, child and adult as a delineation of the two aspects of concept formation were really a matter of ambiguity because both the child and the adult could behave in the genetic and problem-solving forms. However, his explanation served as a good indication of the degree of progress in the educational research on conceptual activities. In this connection Bruner and his coworkers said:

> . . . he is seeking defining attributes that will distinguish examples of these two classes [of mushroom in terms of the ultimate criterion of edibility]. In this sense, we speak of his task as one of concept attainment rather than concept formation. If his task were that of attempting to sort mushrooms into some meaningful set of classes, . . . then we might more properly refer to the task as concept formation. Concept formation is essentially the first step en route to attainment . . . Attainment refers to the process of finding predictive defining attributes that distinguish exemplars from nonexemplars of the class one seeks to discriminate (1956, p. 22).

From this, many of Piaget's research studies were examples of concept formation. Wadsworth made the point very clear by saying:

> Piaget does not say how or under what specific conditions conceptual development can be advanced. In addition, the consequences of advancing development are not clear. Unfortunately for education, Piaget has been concerned with how concepts develop and not how to develop concepts (1972, p. 132).

In summary, the two terms can best be kept apart on the basis of connotations of the end product. Studies of concept formation are likely to furnish information as to the origin of concepts while studies of concept attainment are intended to explore and evaluate strategies of selection and reception in problem-solving situations. Presumably, it can be concluded that concept formation is concerned with the original human action of conceptualization in contrast with concept attainment which concentrates on information processing aspects, in other words, on how concepts are utilized in diverse situations.

Conceptual Studies in Physics Teaching

Research Concerning Physics Teaching

During the 1930's, research studies relating to concept attainment in learning of science appeared. Bedell (1934) used his recall and inference tests to determine the relationship between the ability to recall and the ability to infer in specific learning situations. He pointed out that the only group of students who could infer a fair number of generalized science principles from rather typical general science situations was the upper twenty-five percent in intelligence. Haupt (1935) determined some ideas concerning the phenomenon of "light-life" by asking children to tell all they could about light. As a result, 641 distinct elements were found to appear with a total of 4,003 times.

In the field of physics, research studies of concept learning may be traced to the work of Black (1930). He asked students to write down the first ten words they thought of, when being shown a certain selected word, so as to determine to what extent the scientific concepts of heat, light, gravity, mass, and weight were developed in students' conceptualization. His conclusion was that the associations formed were interesting but threw little light on the students' concepts.

A research study relating to children's generalization ability in observation of pendulums and their motions was the work of Croxton (1936). No significant differences in the ability to generalize were found between the junior high school pupil group and the intermediate grade pupil group.

The post-Sputnik science education reform movement had an impact on the research in concept attainment. Under the auspices of the National Science Foundation, Paul E. Johnson (1964, 1967 and 1969) started a series of research studies in physics teaching on the basis of the hypothesis of Margenau (1950). According to the latter's description, the concepts of physical theory had two kinds of definition: constitutive and epistemic. Constitutive concepts in physics were defined primarily by their relations with other concepts, whereas epistemic concepts were defined primarily by rules which relate the framework of the theory to environmental data. The former concept was, therefore, relational, and the latter was operational. To be sure, a relational concept could also be given an operational definition and vice versa, dependent on situations where a specified definition was required for the solution of a physical problem.

Johnson's work led to the following statements about concept attainment in physics learning: 1) the sample students enrolled in physics responded with more physics terms as associates to a physical concept than students not enrolled in physics; 2) the number of equation-related responses (or constrained responses) given by students was positively correlated with their success in solving problems constructed from these equations; 3) students gave more associates to concepts occurring more frequently in texts than to concepts occurring less frequently; 4) high achievers, on the average, gave a greater number of associates to all of the stimulus words than did low achievers; and 5) achievement and word associations increased from pre- to posttest.

Some of Johnson's work has been confirmed by other researchers. Gardner (1968) found comparable results in requesting two classes of seventh grade students to react to twenty-five social-science concepts used as stimulus words. Verplanck (1967) reported substantial correlations between the frequency of occurrence of associated words and the course grades of subjects enrolling in psychology. Rothkopf and Thurner (1970) found that the increase of instructional input was accompanied by the increase of verbal output in subjects' written essays about nineteen concepts from Newtonian Mechanics.

Although Johnson stated that his measurement of an individual's behavior by means of the word-association test was a continuation of hypotheses of Deese (1966), his application of word associations to physical theories also had some similarities with the work of Black. Although the associations were not found relevant to the student attainment of physical concepts during Black's time, the improvement made in the last decades in the research techniques for conceptual variables paved the way by which both Johnson and Shavelson reached a number of successful conclusions.

Recently, Shavelson (1973) followed the same approach by eliciting students' word associations to physics concepts during learning in a repeated measures design and by collecting aptitude data to provide additional information about student learning from texts. Forty high school students participated in his study and were divided into the instruction and control groups. Shavelson found that the instruction group showed a significant gain in physics achievement from pre- to posttest. No such gain was found for the control group. The number of responses given by students in the instruction group increased significantly from test to test. This was also true in the tallying of constrained responses. For the control group, the number of responses increased initially and then leveled out well below the instruction group.

Garskoff's work was designed along a different direction for the purpose of studying the degree of overlap between two associates. He said:

> The number of perceived similarities may depend on the number of common associates existing within the hierarchies of the two stimulus words . . . . The relatedness of two words (u and v) is defined as a function of the degree to which their respective [associative] meanings (A and B) intersect or overlap (1963, pp. 279-280).

In summary, the research work concerning students' concept attainment in science teaching focused, at the early stage, on promoting children's generalization through instructional situations. The same line of thought, which the psychologists have relied on, was followed by the science education community. Garone stated, in defining concepts:

> Concepts represent the ultimate essence of past experience, and provide the embryonic structure for present and future experiences. Concepts are organizations of experience. They are individualized networks of mental configurations . . . . Interpretations enable children to make generalizations concerning percepts (1960, pp. 104-105).

Similarly, Butts said:

> Since it has been asserted that a child himself is in the most strategic position to know and to select those data from the experience which fit most closely to his cognitive needs, this procedure [of instruction] was specially designed to keep each student independent in his search for understanding. Through his independence in the discovery process, the student was

> forced to rely upon his own cognitive capacities in order to see the relationship between phenomena of this experience and his past experience (1963, p. 138).

Though the above two statements were made in the early 1970's, they fit quite well with the present trends in research of concept learning in science education.

In addition, conceptual research in science education has been in favor of microscopic approaches. Atkin pointed out this inclination by saying: "In the field of educational research and development, we need a swing of this micro-macro pendulum - a swing toward the macro" (1967-68, p. 344). This statement in its context was made to indicate the importance of both the micro and macro extremes, and research work going on at both these ends should be the one best fitting the paradigm. On the other hand, Johnson said ". . . associative relations among words were marked by more dominant responses" (1965, p. 223). The word "dominant" implied the presence of "competition" between microscopic elements, and thus clear distinction of the competitive interactions among the elements of a concept in students' cognitive activities under specified conditions was the only way by which the process of conception was made understandable.

Word Association Test

Galton (1883) conducted one of the earliest word association experiments. He prepared seventy-five stimulus words and accumulated 505 ideas in a total of 606 seconds.

Galton's work was repeated and elaborated in Wundt's laboratory by Trantscholdt (1938). The latter introduced the technique of having an experimenter announce the stimulus words to the subject and contributed a classification system with results comparable to Galton's.

Beginning in the late 1890's, there were numerous methodological improvements. For example, Cattell (1887) used voice and lip keys in word association tests.

Galton's initial experiments laid the foundations for clinical use of the word association tests, as in the work of Jung (1918). Jung's major improvement was standardization of the methods of administration and interpretation. John Elderkin Bell (1948) summarized Jung's work by indicating that a norm group would have to be developed for every group studied, an implication for individual differences.

Flavell and Draguns (1958) used the word association tests to study the microdevelopmental pattern of concept formation. Similar applications were found among those who were interested in science teaching.

In summary, the history of word association techniques was one of high expectation. It has been shown that the implicit word associates of a stimulus word were elicited when the stimulus word was presented, and that these implicit word responses might have a learning function.

Sargent quoted a passage from Wells and Woodworth which concluded: "Few procedures in experimental psychology have so richly rewarded their investigators with the possibilities of practical application as the association method" (Sargent, 1945, p. 265).

In examining the relationship between concept formation and word associations, Rapaport made the following statement:

> the more the relation of stimulus - and reaction - words approaches a coordinate conceptual one, the more the association can be considered neutral; the more it departs from this - in the subordinate or the superordinate direction, or by abandonment of conceptual relation - the more it can be considered as as association disturbance.(1946, p. 21).

Staats, from the point of view of the stimulus-response mechanism, made the following statement:

> On the basis of implicit sequences of verbal responses, it would be expected that any serial chain of word associates, that is, word responses, would demonstrate concept characteristics in the instrumental conditioning situation (1968, p. 150).

Effects of the association behavior on cognitive processes were made clearer in the statement made by Wilson: "The process of generating hunches can be the result of free-association, recall, or induction of classification, relationships, or tentative causes for observations" (1973, p. 1). Among these components, except that the tentative causes were thought of as belonging to free association, the remaining three were all retrievable through students' careful listing of associated words.

Moreover, according to Margeneau (1950), the words which labeled concepts in the language of physical theory have two kinds of meaning: the meaning which permitted a clear understanding of the relationships existing in the subject matter and the meaning which permitted knowledge transfer. In this connection, the word association test seemed to be quite satisfactory when used to elicit classificatory, correlational, and inferential conceptual elements in physics.

Cultural Factors

This section deals with cultural effects on individuals' perceptions and cross-cultural comparisons made in the field of science education. In addition, a description of essential factors characterizing cultural differences is included.

Linton explained individual differences in connection with culture by saying:

> Culture must be considered the dominant factor in establishing the basic personality types for various societies and also in establishing the series of status personalities which are characteristic for each society (1945, p. 151).

Lloyd-Jones and Rosenau (1968) summarized Linton's work by indicating the dual characteristics of a culture. That is to say, the culture as a whole, in spite of reflecting the infinite number of minor variations, could also exhibit some common features.

In this sense, the dual view of the individual provided a foundation for many researchers to carry out cross-cultural comparisons. Similarities were expected to result from a common origin whereas variations might give rise to different findings.

According to Klausmeier and his coworkers (1969), four aspects were considered as important in conception, that is, the complexity of the attributes of objects or events, the rules by which the attributes were joined to form a concept, the number of attributes joined, and the mode in which the examples of the concept were experienced. Thus, an individual's acquisition of a concept was by no means identical to others', especially in cases where cultural differences existed.

In this connection, the International Association for the

Evaluation of Educational Achievement (IAE) initiated a science project which was intended to investigate relationships between the science achievement and attitudes of students, and various home, student, school, and teacher factors. Rosier described the main intention of the IEA surveys by making the following statement:

> . . . the main IEA analyses are devoted to investigating patterns which explain differences in achievement within each country between schools and between students. An important justification for the cross-national nature of the project is to obtain a set of parallel patterns from which generalizations may be drawn. In this article, although we are interested to see how the level of science achievement in Australia compares with that of other countries, we are more concerned to investigate reasons for the cross-national differences which were obtained (1973, p. 77).

In observing the differences in cultural backgrounds, the following components can be cited as essential: religious belief, moral philosophy, value system, power structure, language pattern, living habit, hereditary differences, written language, community structure, national norms in general, family tightness, economic development, population density, industrial achievement, historical background, geographical conditions, and ethnic characteristics. Taking all these factors into consideration, a study of the cultural influences on conceptual development must be a pressing problem if the evolutional processes are to be accounted for.

Overall Framework for Integrated Functional Study

Kendler analyzed the status in the study of concept learning by asserting:

> It is customary after delineating different theories to summarize the recent research under rubrics related to each

> position enunciated. This custom has been handed down from the time when psychology was dominated by schools, and when research by one group was not relevant to that by other groups. Such insularity does not seem to be the case for concept formation. One is at a loss to know whether it is because the area is so advanced or so primitive. Perhaps it is because the preliminary analyses consisted of approaches that are neither mutually exclusive nor contradictory . . . . (1961, p. 452).

In this connection, while externalization and microscopic analyses of the process of concept formation or attainment have been given much attention, the original contract appearing between the behavioristic and the Geneva schools has been diminishing. Nevertheless, a verbal definition is of little use to the psychologist (Heidbreder, 1946). Thus a precise functional definition of conceptual activities is essential which, eventually, leads to the microscopic research of conceptual attainment in terms of more concrete, explicit associated attributes.

In summary, a combination of various theoretical schools is by all means the most functional approach to the understanding of diversely hypothesized mental activities. In this connection the whole of Gestalt psychology must be acknowledged as well as the important sphere of embedded experience, by which its very nature, constitutes an ungestalt. Also, the scientific tool which enables the data collection from experiments can be used in conjunction with the subjective elucidation of concept elements. As a matter of fact, an adjustment of opposing principles in the design of an educat research seems to be more fruitful than sticking to a specified school theory, making it possible for a researcher to override glaring contradictions and thus get on with the business at hand.

On account of the Gestalt notion that the whole cannot be understood by an analysis into its sensory elements, the attributes of the whole are to be particularly experienced as an additional element. To meet this requirement, if the subjects of an experimental study are exposed to the "whole" stimulus word of a word association test, then the research study can hopefully stand up to Gestalt arguments. In addition, the following procedures seem to be adequate to maintain the same view: the use of the contrasting physical concepts such as mass and weight to provide the prerequisite heterogeneity of stimulation, the scrutiny of a dim general stimulus into the embedded clear and distinct ideas to reveal phi phenomena and intuitive hunches, and the grouping of concept elements to reflect their combined functions in the explanation of the whole, either positive or negative.

From the behavioristic view, the elucidation of concept elements by subjects may be criticized as of the introspective type. This is true to some extent, but a compensation can be provided by the accompanying use of a problem-solving test which permits a subject's objective examination of his own mental activities. If the pre- and posttest design is adopted in the word association test, the subjective property is reduced because of the subject's practice of logical thinking in problem solving activities.

As the interaction of maturation, experience, social interactions, and equilibrium are taken as the major factors in Piagetian cognitive development, cultural backgrounds can of course be used for diagnostic purposes in conceptual activities.

To conclude this chapter, the following quotation from Staats' comprehensive account of learning and its relationship to the analysis of language is worthy to be introduced.

> . . . the psychology of learning, as well as psychology in general, became very separatistic. A major part of the field was broken into warring factions that proceeded to develop separate research procedures, separate philosophies of science, and separate terminologies (theories). For a long time the matters of greatest importance in the field involved the contests between the major approaches . . . .
>
> Thus, although the restriction of psychology of learning to simple behaviors, simple situations, and simple organisms, was a part of the growth of the science, the separatism that has been described in the field, at least as the field pertains to human behavior, can now be seen as an anachronistic obstacle to the creation of a general theory of human behavior. And this obstacle has had serious disadvantages . . . .
>
> . . . .
>
> Thus, in summary, a very important aspect of a learning theory of human behavior must involve the selection, integration, and derivation of a comprehensive set of heavyweight learning principles from among the confusing mass of experimental findings and theoretical controversies that are presently available, as well as from naturalistic observations and concepts (1968, p. 5).

CHAPTER III

PROCEDURES

This chapter consists of sections dealing with the selection of the sample (schools and students), selection of the two physics concepts, (mass and weight), selection and evaluation of instruments, collection of data, and analysis of data.

Selection of Sample Schools and Sample Students

The main purpose of this study was to investigate the effects of differences in cultural background on the perception of elements involved in two PSSC physics concepts for two subject groups, selected in Worthington, Ohio, U.S.A., and Taiwan, the Republic of China.

A description of the PSSC courses offered at these two places seems to be necessary. The PSSC course was the first curriculum project developed in the science education reform movement in the U.S.A. during the late 1950's. Although the present student enrollment in the course is low, PSSC is still offered as an elective subject by a certain number of schools in the U.S.A.

In Taiwan, the PSSC course was adopted in 1966 in the secondary-school curriculum as a requirement for all senior-high students. Because most of the materials used in Taiwan, including instructional texts, manuals, teachers' guides, audio-visual aids, achievement test forms, and experimental equipment, are either translations or imitations of the United States originals, the course offering in these two places is probably similar. Each week, in Taiwan, the students receive basically three hours of lecture and three hours of laboratory work with possible variations depending on the emphasis the individual school puts on the implementation of specific educational objectives.

Selection in the U.S.A.

The selection of the sample schools determined the student population. Similarities in characteristics of the selected schools became the most important criterion for obtaining two student groups identical in most aspects except that of cultural backgrounds. Taking into account the community structures in the urban and suburban areas of the U.S.A., a school in the suburban area was the most preferable. Most high school students in Taiwan, pursuing a higher education course of study, are generally of a better socio-economic status, dissimilarities of a socio-economic nature of the Taiwan subject group from the U.S.A. group would be decreased through such a selection of a suburban U.S.A. high school. Worthington High School administration and teachers agreed to allocate enough time for the investigator to administer two word association tests and a problem-solving test, and thus it was used as the sample school.

Selection in Taiwan

Taiwan does not have a community structure similar to that of the U.S.A. Location of a community is by no means an indication of the socio-economic status of its inhabitants. To reflect a mixture of local situations, the sample schools were selected from diverse parts. The four regions of Taiwan from which the schools were selected for the study included the northern, the middle, the southern, and the eastern areas.

Coeducational public high schools located in the neighborhood of a city in these four areas were the targets of the selection, unless specified otherwise. Such an arrangement had the advantage of avoiding the inclusion of the elite or underprepared students of private schools and of securing a Taiwan student group with a coeducational background comparable to that of the Ohio group.

The population distribution in Taiwan in 1970 was as follows: 3,002,217 in the northern part, 4,617,432 in the middle, 5,535,238 in the southern, and 1,361,388 in the eastern (China Yearbook 1970-1971). It was decided to keep the numbers of the students selected from these four regions approximately proportional to the inhabitant ratio.

Matching Techniques

The student subjects enrolled in the Worthington High school PSSC course were found to consist of eleventh and twelveth graders whereas the Taiwan sample students were all in grade twelve. As stated by Helgeson, "Maturity, as indicated by grade level, appears to be a factor in determining success for these eight concepts [of forces], particularly at the high levels of understanding" (1968, p. 37). The homogeneous nature of the selected student groups became a matter of concern. Since measures of intelligence had been commonly employed in the graded system as bases for grouping of students (Keliher, 1931), the matching techniques in terms of intelligence quotient were adopted in this study, particularly for the purpose of minimizing the differences resulting from the diversity of grade levels.

Certainly it is unreasonable to say that the individuals of the matched pairs were mirror images of one another. Indeed, they still differed to some extent in innumerable physical and mental features. However, matching techniques had the advantages of reducing the inherent errors present in a design. Cornell discussed paired measures as follows:

> The reason for matching is to reduce the error variance, that is, to increase the precision of the experiment. If the bases upon which subjects are matched is such that pairs will be highly correlated in the measures used in the outcome of the experiment, the experimental error is greatly reduced. This increases the chance of finding a significant difference between the two populations if the true difference is not zero (1956, p. 227).

Two days of testing were permitted in the Worthington district; therefore, administration of a battery of tests for matching purposes was impossible. Instead, student cumulative folders were used as substitues to yield the following matching measurements: a score on the California Test of Mental Maturity, a score on reading ability, and scores in chemistry and biology courses. Averages of the scores in chemistry and biology courses were further calculated to serve as a basis for assessing students' understanding of science. In other words, a total of three matching measurements were obtained for each of the Worthington High School students in the study.

To form a matched pair of students living in Ohio and Taiwan, the Taiwan students involved in this study were given the California Test of Mental Maturity to measure their intelligence quotients. Each Taiwan student's scores in reading ability and science courses (chemistry and biology) were also obtained from the records. These scores were used to match his or her Worthington High School counterpart. That is to say, a pair of matched students had the same sex, the same average scores in science and reading ability, and the same intelligence quotient. The students involved in the study were identified by number to avoid identification of specific individuals. The data analysis was limited to these matched pairs.

Analysis of Two PSSC Concepts

The selection of two concepts from the PSSC textbook involved the following criteria:

1. The two concepts should have been taught to all the students involved in this study;
2. The two concepts were clearly defined in physics;
3. The two concepts showed some kind of semantic ambiguity when used in leading one's everyday life, and their implied meaning could provide students of different cultural backgrounds with varying ideas;
4. The two concepts should have so close a relationship that their overlapping elements and their simultaneous involvement in a test item were quite possible;
5. Formation of the two concepts in the students' cognitive domain should depend upon some kind of hierarchical structures.

The concepts, mass and weight, are presented in the first part of the PSSC textbook and used throughout the material. Although the physical definitions of mass and weight are given distinctively, students typically have difficulties with their clear identification. Especially in everyday life, the units of these two concepts might provide a student with great ambiguity. As far as the implied meaning was concerned, mass could have as varied a meaning as the service of the Eucharist in English and as "quality" in Chinese.

The involvement of a hierarchical structure in the mass-weight concept formation was also apparent, due to the fact that mass and weight are further accounted for in the third part of the PSSC textbook. One can find in the textbook that the mass-weight concepts are first defined in terms of space, time, and materials and then in terms of vectors and energy.

Historically, many efforts have been made by the physics community to clarify for students the distinction between mass and weight, even in terms of their measurements (Bender, 1973). Hence the selection of these two concepts for designing a study of conceptual elements in physics seemed to be justifiable.

Selection and Evaluation of Instruments

The selection of instruments was based on the scope of the study. The four aspects on which data were collected were: those concerning personal characteristics of the student; the elements involved in two physics concepts as perceived by the student; the physics test items used as a learning task to attempt to influence the student's perceptions toward the deletion or retention of conceptual elements; and the level of importance at which the student ranked a conceptual element. The decision was made to utilize data from instruments previously administered to the students as a part of the school's assessment program.

The instruments used in the study, therefore, included the California Short-form Test of Mental Maturity, 1963 Revision (Level 5) (CTMM); a word association pretest (Exercise One); a word association posttest (Exercise Two); a mass-weight problem set (Questions on Mass and Weight); and a modified Likert-type scale of importance.

The first test has been available since 1963, and its Chinese version was used to measure the intelligence quotients of the Taiwan student group. The last four tests were developed especially for use in the present study and were administered to both the Worthington and the Taiwan student groups. The Worthington High School students were not given the CTMM test because the scores were on file.

Chinese Version of California Short-form Test of Mental Maturity. 1963 Revision (Level 5)

The Chinese version of the CTMM test was the only test available in Taiwan with the content comparable to that of the U.S.A. original copy. Some changes from the U.S.A. original were made by the Psychology Department of the National Taiwan University to fit local situations.

The Chinese version changed six pictures in the Opposite subtest, six pictures in the Similarities subtest, and three pictures in the Analogies subtest. In addition, the Numerical Values subtest consisting of test items of the manipulation of currency exchange was replaced by the Number Series subtest of the CTMM 1951 version, and the Verbal Comprehension subtest was entirely rewritten. The final copy of the Chinese version included: forty-five items as Opposites, Similarities, and Analogies, fifteen items in each subtest; twenty items as Number Problems; fifteen items as Number series; thirty items as Verbal Comprehensions; and twenty-five items as Delayed Recalls.

A normative analysis of the Chinese version was reported using high school and college students as test subjects. Reported reliabilities ranged from 0.32 to 0.80 for the seven subtests. Tables of norms for converting raw scores into standard scores were also available. (For more information, see Appendices A and B.)

The Chinese version was scaled to the U.S.A. original to obtain the standard score and the total intelligence quotient. Hence, the Chinese version was selected for use in the study to determine the intelligence quotients of the Taiwan student group.

Word Association Tests

In designing the word association tests for use in the investigation, two stages of an association behavior were given special attention, namely, the crude experimental and the intensive introspection approach. The experimental approach stage allowed the student to freely select his association behaviors, whereas the intensive introspection stage was used to induce an elucidation of conceptual elements under a comparatively more restricted situation.

In this study, the word association pretest and posttest were designed to serve the crude experimental approach and the intensive introspection proposes, respectively. To create a more intensive introspection atmosphere, a problem-solving test was administered to the student between the word association pretest and posttest. The purpose of such an arrangement was to provide the student with a chance to refer to his experience acquired in solving test items of the problem set when answering the word association posttest.

The word association pretest, therefore, included an example which was deliberately selected for developing a student's experimental approach. In the pretest the student was allowed to respond freely to the stimulus words through both his close and distant reactions (Bell, 1948) and to write down any kind of words that he associated with the stimulus words.

The word association posttest was intended to deal with the intensive introspective phase. The student was expected to scrutinize the appropriateness of the associated words which he gave in the pretest and to make a decision on their deletion or retention. In addition, the student was allowed to add new associations which he might then consider important. The problem-solving test form was given back to the student during the posttest for reference.

As part of the word association posttest, the student was also requested to check whether his retained and additional associated words had been used in solving each of the test items included in the problem set. The checking process had two objectives. First, the student classified his retained and added associated words into the problem-related or the problem-nonrelated category; and second, he had the opportunity to reconsider his deletion and retention decisions.

The usability of both tests was tested by submitting the first drafts to the graduate students of the Educational Research seminar, offered by the Science and Mathematics Education Faculty, the Ohio State University, for reactions to be used in instrument modification.

The second draft was given to two classes of physics students of Madison High School of Mansfield, Ohio, in a pilot study. According to the results obtained from the pilot study, six minutes was found to be sufficient for elucidating a maximum of forty-two associations with a stimulus word and forty-five minutes was the maximum time required for completion of the posttest.

The content and instructions included in the word association tests were again revised based on the recommendations and responses of the pilot study students. (For the sample copies of the word association pre- and posttests, see Appendix C.)

PSSC Problem Set

The PSSC problem set was devised to assess a student's ability to apply the classificatory, relational, and inferential nature of conceptual elements to a real situation. To construct the problem set, a series of classificatory, relational, and inferential statements were formulated on the basis of the investigator's perceived conceptual elements. Each statement was first used to build the "core" of a problem, and then, the "core" was made less marked by associating secondary conditions with it.

The major function of the problem set was to direct a student's mind to the physics area in his revision of associations. Thus, reliability and validity were not the main concerns in test preparation. As a minor objective, the problem set also served to evaluate the student's academic achievements in physics by means of which the cut-off value for dichotomizing a student group into the high-achiever and low-achiever subgroups was determined. In this sense, the calculation of the test reliability seemed to be necessary. The Kuder-Richardson formula 20 yielded r = 0.269 for the Worthington student group and 0.320 for the Taiwan group, and the Kuder-Richardson formula 21 yielded r = 0.047 for the Worthington group and -0.043 for the Taiwan group. Internal consistency was low for both groups.

The problems were first sent to the Educational Research seminar of the Ohio State University for recommendation and correction, and then, tried out in the Madison High School of Mansfield, Ohio, as a part of the pilot study materials. The pilot study results showed that a maximum of 20 minutes was enough for a student to complete the whole problem set. (For detailed information about the formulated statements and problem set, see Appendix D.)

Scale of Importance

For a given concept, a student might list many associated words, but would not necessarily perceive them as having equal importance. The more important a conceptual element was perceived, the more fundamental the element seemed to be in the student's cognitive structure. Taking into account the hierarchical structure of the physics subject matter, the elements with similar indices of importance might have the highest correlation. In this sense, the arrangement of elicited elements in an order of importance provided a preliminary condition for grouping of elements. This is the necessary condition for the use of the B-coefficient statistics.

A scale of importance was designed to allow the student to rank his own associated words. The scale was basically of the Likert type. The major modification was that the student did not use a pencil to assess the importance of each of his associations and that a different number of associations could be ranked on the scale. The following is a description of procedures.

After a student turned in his word association posttest, each retained or added associated word was copied down by the investigator on a card. The cards, with one association on each card, were given back to the students who were asked to rank them in an order of importance. For each student, there were two packs of cards to be arranged in order: one for mass and the other for weight.

In mathematical operations on the importance index, two kinds of calculations were used. When the importance index of a conceptual element perceived by one student was to be added to that of the same element perceived by another student, the sum was determined by a simple addition of the two importance indices. When the importance sum was calculated for two different elements perceived by the same student, the importance indices were first converted into ratios and then added.

The ratio was calculated using the formula:

$$\frac{I_i}{\frac{n+1}{2}}$$

I_i = the importance index of an individual element,

n = the number of elements perceived by the student who identified this individual element.

An overall importance index was calculated for each student in terms of his problem-related or problem-nonrelated conceptual elements to assess the importance difference between these two categories of conceptual elements. An overall importance index was calculated for each of the associated words for a specified student group and served as an indicator of the sequential order of the associated word in factor analysis. In other words, the clustering of associated words was basically determined on the basis of the student's own perceptions.

Schedules for Test Administration

The schedule for test administration in Worthington, Ohio is shown in Table 1. The schedules for test administration in Taiwan, the ROC, are shown in Tables 2 and 3.

Collection of Data

Procedures

Procedures for collection of data were approved by the school administration. The names of students enrolled in the course were obtained from their physics teacher. Biology, chemistry, and reading ability scores were supplied by the guidance counselor. The intelligence

TABLE 1

SCHEDULE FOR TEST ADMINISTRATION, WORTHINGTON, OHIO, U.S.A.

	First Day*	Second Day*	Third Day
Tests Administered	Word Association Pretest and PSSC Problem Set	Word Association Posttest	Scale of Importance**

* One class period on each day.
** Scale of importance given as an extracurricular activity.

TABLE 2

SCHEDULE FOR TEST ADMINISTRATION IN NORTHERN PART OF TAIWAN, ROC

	First Day*	Second Day**	Third Day*
Tests Administered	Word Association Pretest and PSSC Problem Set	Word Association Posttest and Scale of Importance	CTMM

* One class period on the first and third days.
** Two class periods on the second day.

TABLE 3

SCHEDULE FOR TEST ADMINISTRATION IN CENTRAL, SOUTHERN, AND EASTERN PARTS OF TAIWAN, ROC

	First Day*	Second Day*
Test A Administered	Word Association Pretest, PSSC Problem Set, and CTMM	Word Association Posttest and Scale of Importance

* Two class periods each day.

quotients and current grade level of the Worthington High School student group were obtained from the files. For the Taiwan student group, the intelligence quotients were determined through the use of the Chinese version of the California Test of Mental Maturity, 1963 Revision (Level 5).

In Mansfield and Worthington, Ohio, all the test instruments were administered personally by the investigator in cooperation with the physics teacher. A student teacher also assisted in the Worthington High School study. Instructors of the Taiwan Provincial College of Education, who had participated in a discussion with the investigator prior to test administration, assisted in collection of data from the Taiwan student group. Written instructions were provided with each test and kept standard so directions by the instructors were not necessary except in the CTMM test.

All of the tests were corrected by the investigator. The scores were not used for grading purposes in any of the schools involved.

Timetable for the Study

The sequence of the study was as follows:

January 14, 1974	Preliminary pilot study with the seminar participants at the Ohio State University
January 24, 1974	Pilot study at the Madison High School, Mansfield, Ohio
March 5-7, 1974	Administration of the test instruments at the Worthington High School, Ohio Matching variables obtained.

March 25-27, 1974	Administration of the test instruments in the northern part of Taiwan Matching variables obtained.
April 1-2, 1974	Administration of the test instruments in the southern part of Taiwan Matching variables obtained.
April 10-11, 1974	Administration of the test instruments in the eastern part of Taiwan Matching variables obtained.
April 15-16, 1974	Administration of the test instruments in the middle part of Taiwan Matching variables obtained.

Analysis of Data

At this point, one thing should be made clear concerning working with existing groups. That is, failure of randomization in the study might eventuate in criticism. There seemed to be no way to statistically attribute the results from the present study to a particular cultural factor. However, in cases where Linton's definition that "a culture is the configuration of learned behavior and results of behavior" (1945, p. 32) is acceptable, it is reasonable to infer that the individual students involved in this study had been "treated in all respects" by their cultural patterns. This treatment is apparently everlasting for an individual's entire life time and is innately and postnatally random. By "innate," nobody could select a culture prior to his life, and by "postnatal," the individual is randomly assorted to a culture and treated by its pattern from the very beginning of his life. This should be true, especially for students in the eleventh or twelveth grade. Moreover, there was no predetermined reason for the investigator to select a specified group of students at a specified time and a specified place, except that matching requirements were to be fulfilled. Under such a situation, the only purposeful influence on a student's cognitive understanding of physics concepts comes from his daily school life, of which the most important intervening and technically determinable variables were controlled through the use of matching techniques.

Due to the fact that a culture is almost all-inclusive, it appears reasonable to say that sources of errors from failure of randomization in this study were partially controlled by the matching process, with the remaining sources of difference attributable to the cultural differences. The following is a description of data analyses designed along this line.

The data analysis consisted of five parts:

1. The tabulation and calculation of the scale of importance and of the numbers of various kinds of elements perceived in two physics concepts by the students.
2. The item analysis of the PSSC problem set.
3. The analysis of variance of the numbers of various kinds of elements perceived by a specified student group or subgroup.
4. The computation of correlation coefficients among conceptual elements.
5. The cluster analysis of conceptual elements.

Tabulation and computation were made for the culturally-different student groups and their dichotomized subgroups concerning the following factors:

1. The total number of conceptual elements.
2. The numbers of problem-related and nonrelated elements.
3. The number of physical science elements.
4. The number of everyday conceptual elements.
5. The numbers of deleted and added elements.
6. The averages of importance indices of problem related and non-related elements.
7. The numbers of overlapping and exclusive elements.
8. The numbers of correct and incorrect uses of conceptual elements in the solution of the problem set.

The item analysis was undertaken to determine the statistical variables of a specified item. The item analysis package developed by the Center for Measurement and Evaluation of The Ohio State University was used.

A two way analysis of variance was conducted to test the hypotheses stated in the first chapter. The MANOVA program distributed by Clyde Computing Service, Coconut Grove Station, Miami, Florida, was run for factorial design.

Calculation of correlation coefficients among conceptual elements was made in terms of the correct uses of physical science conceptual elements in the solution of problems. The elements were arranged in the order of average importance indices. The BMDO3D program was used for correlation determination and for punched card output.

The cluster analysis was made for each specified student group and subgroup. The purpose was to group diverse variables into clusters. The B-coefficients were determined for a combination of the variable elements and served as an indicator of clustering judgment. The decision to include a variable element in a cluster was based on the number of points drop in B-coefficients. A Fortran IV program was especially developed in this study for B-coefficient calculations (Appendix E).

In testing the significant difference of the characteristics between two subgroups, a two-way analysis was conducted using the MANOVA program.

Summary

The investigation was designed to assess cultural effects on the perception of conceptual elements involved in mass and weight for students of the high schools in Worthington, Ohio, the U.S.A. and Taiwan, the ROC during the 1973-74 school year. The sample consisted of twenty-six students enrolled in the PSSC course at the Worthington High School and 358 students in the high schools scattered in diverse parts of Taiwan. Missing data and matching requirements necessitated the elimination of seven Worthington students; therefore, the analysis was made for thirty-eight students, or nineteen pairs, half from Worthington High School and half selected from the Taiwan high schools.

Graphically, the analysis of variance and the design of the study are illustrated in Figures 1 and 2.

Figure 1

Graph for Two-way Analysis of Variance

	Worthington	Taiwan
High Achievement	$X_{1,1,1}$ $X_{1,1,2}$ $X_{1,1,3}$ $X_{1,1,4}$ $X_{1,1,5}$ $X_{1,1,6}$ $X_{1,1,7}$ $X_{1,1,8}$ $X_{1,1,9}$	$X_{1,2,1}$ $X_{1,2,2}$ $X_{1,2,3}$ $X_{1,2,4}$ $X_{1,2,5}$ $X_{1,2,6}$ $X_{1,2,7}$ $X_{1,2,8}$ $X_{1,2,9}$
Low Achievement	$X_{2,1,1}$, $X_{2,1,2}$ $X_{2,1,3}$ $X_{2,1,4}$ $X_{2,1,5}$ $X_{2,1,6}$ $X_{2,1,7}$ $X_{2,1,8}$ $X_{2,1,9}$ $X_{2,1,10}$	$X_{2,2,1}$ $X_{2,2,2}$ $X_{2,2,3}$ $X_{2,2,4}$ $X_{2,2,5}$ $X_{2,2,6}$ $X_{2,2,7}$ $X_{2,2,8}$ $X_{2,2,9}$ $X_{2,2,10}$

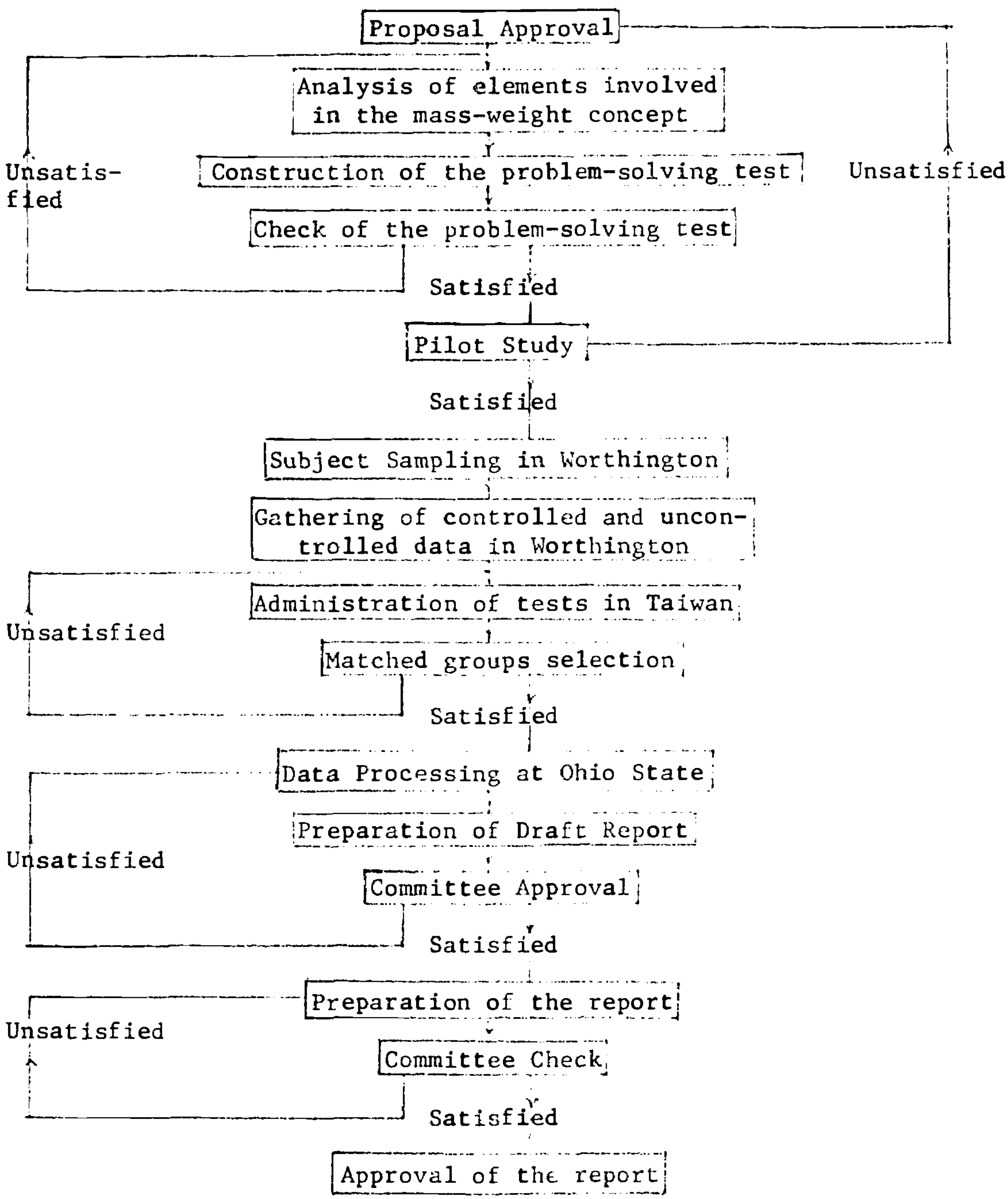


Figure 2. Flow Chart of Design

CHAPTER IV

THE FINDINGS

This chapter contains the presentation, interpretation, and analysis of the data obtained in the study. Included are sections on sample characteristics, conceptual element characteristics, test item analysis, analysis of hypotheses, and hypothetical grouping of problem-related conceptual elements. Each section is presented, evaluated, and summarized as a unit.

Characteristics of Sample

Sample School

The major concern of the selection of a sample school in the U.S.A. was to secure a student group with characteristics comparable to those of the Taiwan student group. The senior students in Taiwan are taught with the PSSC course materials; therefore, a school offering the PSSC course with a sufficiently large student enrollment was desirable. Worthington High School, located in the suburban area of Columbus, Ohio, met these criteria and was used in the study.

In Taiwan, a total of eighteen similar schools was considered for selection. These schools included twelve public coeducational high schools in the middle and southern regions, four private coeducational high schools in the northern region, and one public boys' high school and one public girls' high school in the eastern region. Most of these schools were located in the neighborhood of a major city of Taiwan, except those in the northern region. Inclusion of boys' and girls' schools was due to local situations: no coeducational school in the eastern (Hualian) area.

Five Taiwan schools were selected to be used in the study. These included one school in each of the northern, middle, and southern areas and two schools in the eastern area. The schools selected in Taiwan are shown in Table 4.

Matched Sample Student Groups

A total of twenty-six students enrolled in PSSC physics at Worthington High School was selected and given the instruments used in the study. However, data from only nineteen students were analyzed because of missing data and of matching requirements.

A breakdown of the Worthington High School students involved in the study is shown in Table 5.

A much larger student group in Taiwan was given the tests used in the study in order to facilitate matching. A total of 358 students was involved. All the students tested were in the twelfth grade. The tested student distribution is shown in Table 6.

Table 7 shows the relationship of the sample distribution and population distribution by regions in Taiwan.

From 358 tested Taiwan students, nineteen students were selected to match their counterparts in Worthington. Sample student distribution in Taiwan is shown in Table 8.

TABLE 4

SAMPLE SCHOOLS IN TAIWAN

School	Description
Chiang Shu High School	Private, coeducational, Taipei City, northern area
Feng Yuan Senior High School	Provincial, coeducational, Taichung City, middle area
Chien Chen Senior High School	Provincial, coeducational, Kaoshiung City, southern area
Hualian Boys' Senior High School	Provincial, Hualian City, eastern area
Hualian Girls' Senior High School	Provincial, Hualian City, eastern area

TABLE 5

SAMPLE STUDENTS IN WORTHINGTON

Class	Size	Description	
A	9	2 girls	2 11th grade
		7 boys	4 12th grade
			3 Missing data
B	17	8 girls	7 11th grade
		9 boys	6 12th grade
			4 Missing data
Total 2	26		

TABLE 6

TESTED STUDENTS IN TAIWAN

Region	Number of Classes	Class Size	Description
Northern	1	36	1 girl 35 boys
Middle	3	38 35 46	22 girls 97 boys
Southern	3	35 43 45	6 girls 117 boys
Eastern	2	41 39	41 girls 39 boys
Total	9	358	

TABLE 7

PERCENTAGES OF TESTED STUDENTS AND POPULATION DISTRIBUTION BY REGION IN TAIWAN

Region	Tested Students (%)	Population (%)*
Northern	10.11	20.68
Middle	33.24	31.80
Southern	34.31	38.15
Eastern	22.34	9.37

*See Chapter III.

TABLE 8

SAMPLE STUDENT DISTRIBUTION IN TAIWAN

School	Number of Selected Students	Percentage
Chiang Shu High School	3	15.80
Feng Yuan Senior High School	4	21.06
Chien Chen Senior High School	6	31.57
Hualian Girls and Boys Senior High Schools	6	31.57*
Total	19	

*A higher percentage resulted from a larger number of female students participating in the tests.

The corresponding matching measures (sex, IQ, reading ability, science grade) for the matched groups in Worthington and Taiwan are shown in Table 9.

High- and Low-achieving Student subgroups

An objective of administration of the mass-weight problem set was to dichotomize the students into high-achieving and low-achieving subgroups, as shown in Table 9. The median score on the problem set was calculated for each of the Worthington and Taiwan student groups and was used to determine the high- and low-achievement subgroups.

Summary

In order to make cross-cultural comparisons, it was necessary to match the students. Sex, intelligence quotient, reading ability, and average score in science (biology and chemistry) were used as matching variables. Subgroups were formed on the basis of achievement on the mass-weight test. The students' scores on the mass-weight test were not used as a matching variable because the Taiwan student group was facing the 1974 annual entrance examination when receiving the mass-weight test and might be strongly motivated in the study of the physics subject matter.

Conceptual Element Characteristics

The conceptual elements were listed in two categories (mass, weight) for each of the Worthington and Taiwan student groups; i.e.,

1. Conceptual elements perceived in the concept of mass by the Worthington student group,

TABLE 9

MATCHING MEASURES OF SAMPLE GROUPS AND ACHIEVEMENT SUBGROUP CATEGORIES

Worthington, Ohio, USA						Taiwan, ROC					
Student ID Number	Sex	IQ	Reading Ability (Percentage)	Science	Achievement Category H = High; L = Low	Student ID Number	Sex	IQ	Reading Ability* (Percentage)	Science	Achievement Category H = High; L = Low
001	M	112	21	D	H	101	M	112	20-29	C	H
002	F	118	91	A	H	102	F	118	90-99	A	L
003	M	132	93	A	H	103	M	132	90-99	A	L
004	M	97	30	C	L	104	M	97	30-39	C	H
005	M	101	2	C	L	105	M	101	0-9	C	L
006	M	110	72	C	L	106	M	110	70-79	C	L
007	M	122	81	B	H	107	M	122	80-89	B	H
008	F	114	98	A	L	108	F	114	90-99	A	H
009	M	123	91	A	H	109	M	123	90-99	A	H
010	F	122	87	A	H	110	F	122	80-89	A	H
011	M	135	94	A	L	111	M	135	90-99	A	L
012	M	112	80	C	L	112	M	112	80-89	C	L
013	M	122	87	A	L	113	M	122	80-89	A	L
014	M	124	95	A	H	114	M	124	90-99	A	H
015	F	130	89	B	L	115	F	130	80-89	B	L
016	F	119	89	B	L	116	F	119	80-89	B	L
017	M	127	89	A	H	117	M	127	80-89	A	H
018	M	128	89	A	L	118	M	128	80-89	A	H
019	M	126	91	A	H	119	M	126	90-99	A	L

*Interval percentage was used to make matching possible.

2. Conceptual elements perceived in the concept of weight by the Worthington student group,
3. Conceptual elements perceived in the concept of mass by the Taiwan student group,
4. Conceptual elements perceived in the concept of weight by the Taiwan student group.

Each of these categories was further divided into problem-related and problem-nonrelated subcategories. The respective numbers of conceptual elements perceived in mass and weight were 101 and 89 for the Worthington student group and 96 and 90 for the Taiwan student group. A summary of the numbers of conceptual elements included in the eight subcategories is shown in Table 10. (For the list of conceptual elements in each category, see Appendix F.)

The total number of conceptual elements given by each student is shown in Table 11.

Figure 3 shows the frequency distributions of the total number of conceptual elements perceived in the mass-weight concept by the Worthington and Taiwan student groups. The modes fell in the range from 30 to 39 conceptual elements for both groups.

Problem-related and Nonrelated Conceptual Elements

The numbers of problem-related and problem-nonrelated conceptual elements perceived in mass and weight differed greatly for individual students. The respective ranges of problem-related and problem-nonrelated conceptual elements were from 9 to 33 and 1 to 22 for the Worthington student group and from 11 to 57 and 0 to 27 for the Taiwan

TABLE 10

CONCEPTUAL ELEMENT CHARACTERISTICS

	Number of Conceptual Elements Perceived in Mass		Number of Conceptual Elements Perceived in Weight	
	Problem-Related	Problem-Nonrelated	Problem-Related	Problem-Nonrelated
Worthington	56	45	43	45
Taiwan	66	30	57	33

TABLE 11

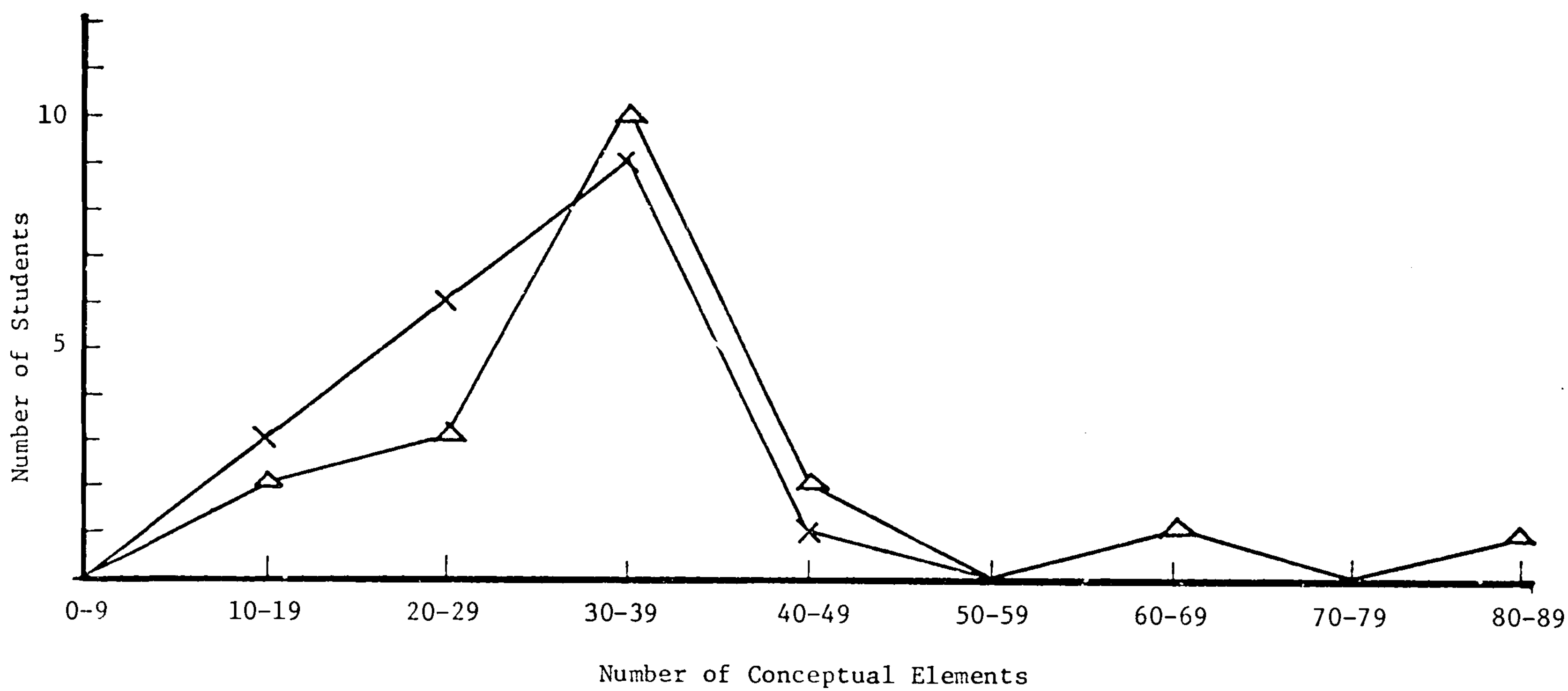
TOTAL NUMBER OF CONCEPTUAL ELEMENTS GIVEN BY INDIVIDUAL STUDENTS

Worthington		Taiwan	
Student ID Number	Total Number	Student ID Number	Total Number
001	11	101	36
002	34	102	33
003	24	103	45
004	14	104	19
005	16	105	39
006	32	106	34
007	30	107	31
008	38	108	62
009	27	109	25
010	20	110	31
011	26	111	81
012	38	112	32
013	37	113	35
014	28	114	49
015	37	115	13
016	37	116	26
017	40	117	32
018	38	118	32
019	28	119	23

Figure 3

Frequency Distributions of Total Number of Conceptual Elements Perceived in Mass and Weight by Worthington and Taiwan Student Groups

x = Worthington Group
Δ = Taiwan Group



student group. A breakdown by student is shown in Table 12.

A graph for the frequency distributions of problem-related and problem-nonrelated conceptual elements perceived in mass and weight by the Worthington and Taiwan student groups is shown in Figure 4. The modes for both groups were found to be in the range from 0 to 9 conceptual elements in the problem-nonrelated category and in the range from 10 to 29 in the problem-related category.

Physical Science and Everyday Conceptual Elements

Distinction between physical science and everyday conceptual elements perceived in mass and weight was based on the characteristics of the students' given terms. Physical terms appearing in the PSSC textbook were identified as physical science conceptual elements. Mathematical terms (e.g., area, volume) were referred to as everyday conceptual elements with the assumption that the students' mathematical skills were not taken into account in the study (see Chapter 1). Most everyday conceptual elements were found to belong to the problem-nonrelated category.

The numbers of physical science and everyday conceptual elements given by an individual student ranged, respectively, from 8 to 29 and 0 to 23 for the Worthington student group and from 12 to 49 and 0 to 40 for the Taiwan student group. A breakdown by student is shown in Table 13.

Frequency distributions of physical science and everyday conceptual elements perceived in mass and weight by the Worthington and Taiwan student groups are shown in Figure 5. The modes for both groups fell in the range from 20 to 29 conceptual elements in the physical

TABLE 12

PROBLEM-RELATED AND NONRELATED CONCEPTUAL ELEMENTS BY STUDENTS

Worthington			Taiwan		
Student ID Number	Number of Problem-Related Elements	Number of Problem-Nonrelated Elements	Student ID Number	Number of Problem-Related Elements	Number of Problem-Nonrelated Elements
001	10	1	101	20	16
002	33	1	102	22	11
003	20	4	103	36	9
004	12	2	104	13	6
005	12	4	105	12	27
006	16	16	106	33	1
007	23	7	107	31	0
008	24	14	108	41	21
009	15	12	109	21	4
010	19	1	110	24	7
011	9	17	111	57	24
012	20	18	112	31	1
013	16	21	113	16	19
014	23	5	114	29	20
015	15	22	115	11	2
016	29	8	116	25	1
017	28	12	117	31	1
018	26	12	118	16	16
019	14	14	119	19	4

Figure 4

Frequency Distributions of Problem-related and Problem-nonrelated Conceptual Elements Perceived in Mass and Weight by Worthington and Taiwan Student Groups

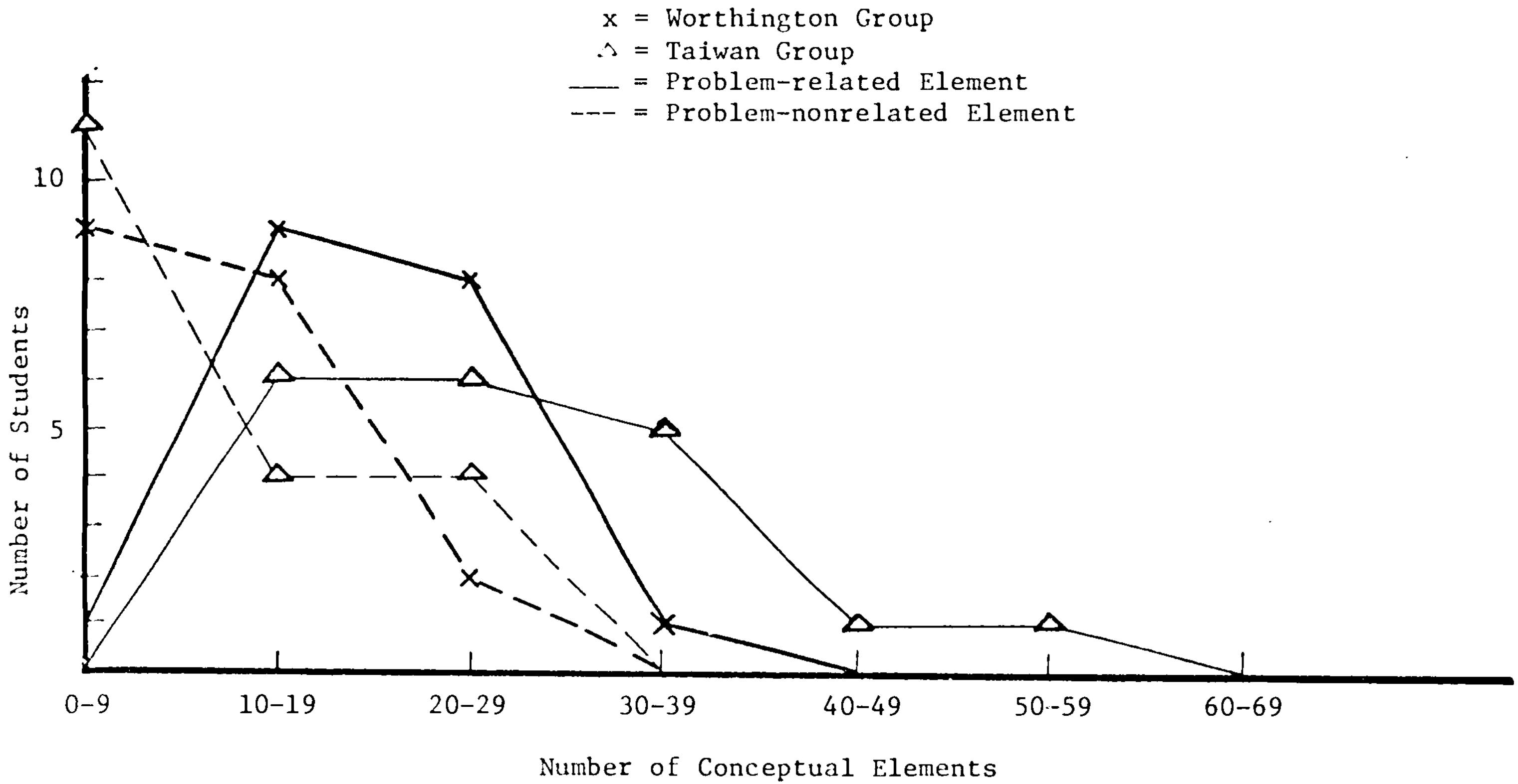


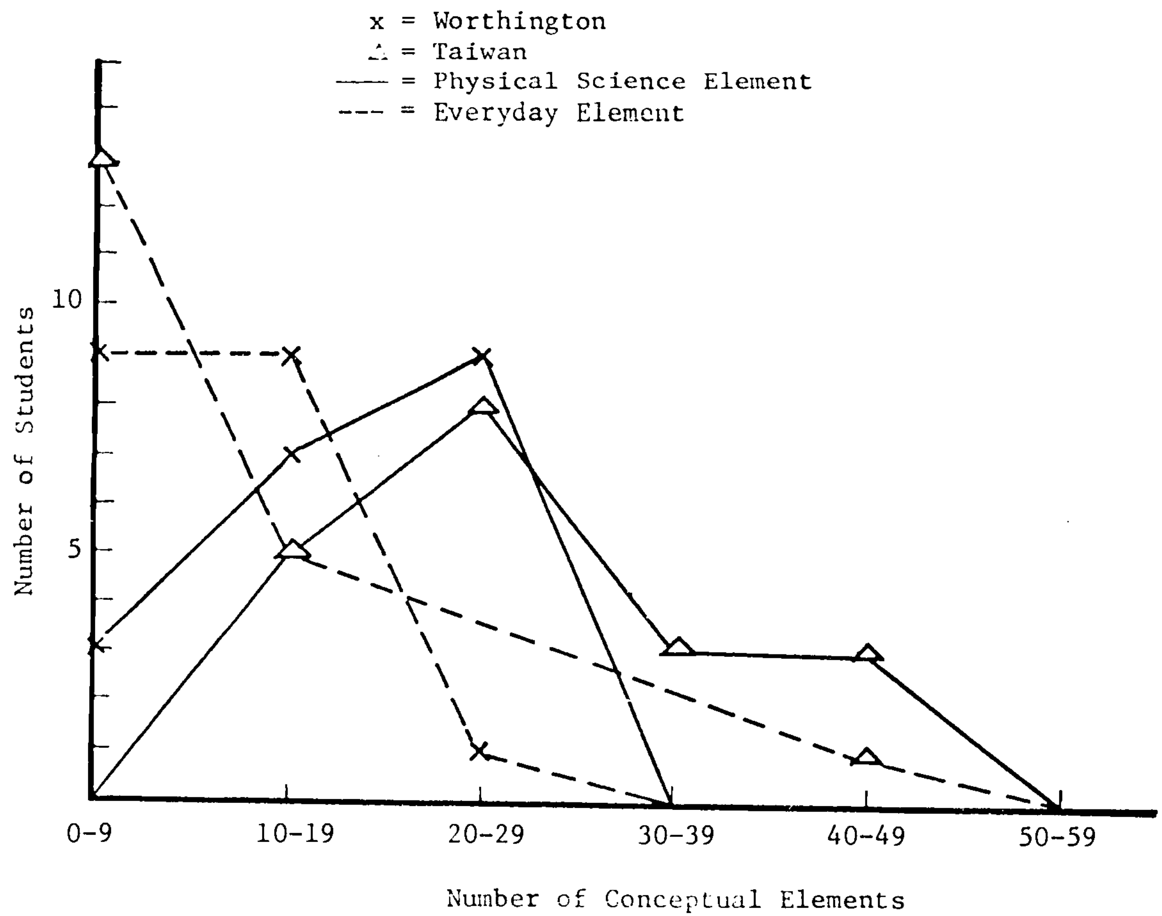
TABLE 13

PHYSICAL SCIENCE AND EVERYDAY CONCEPTUAL ELEMENTS BY STUDENTS

Worthington			Taiwan		
Student ID Number	Number of Physical Science Elements	Number of Everyday Elements	Student ID Number	Number of Physical Science Elements	Number of Everyday Elements
001	8	3	101	28	8
002	26	8	102	23	10
003	23	1	103	45	5
004	9	5	104	19	0
005	16	0	105	30	9
006	21	11	106	30	4
007	23	7	107	28	3
008	25	13	108	49	13
009	15	12	109	24	1
010	15	5	110	29	2
011	9	17	111	41	40
012	27	11	112	31	1
013	18	19	113	29	6
014	23	5	114	27	2
015	19	18	115	13	0
016	29	8	116	18	8
017	17	23	117	17	15
018	20	18	118	22	10
019	14	14	119	12	11

Figure 5

Frequency Distributions of Physical Science and Everyday Conceptual Elements Perceived in Mass and Weight by Worthington and Taiwan Student Groups



science category and in the range from 0 to 19 in the everyday conceptual element category.

Additional and Deleted Conceptual Elements

The respective numbers of additional and deleted conceptual elements perceived in the mass-weight concept ranged from 0 to 7 and 0 to 24 for the Worthington student group and from 0 to 20 and 0 to 33 for the Taiwan student group. A breakdown by student is shown in Table 14.

Figure 6 shows frequency distributions of additional and deleted conceptual elements perceived in mass and weight by the Worthington and Taiwan student groups. The modes for both groups fell in the range from 0 to 9 elements in both conceptual element categories.

Overlapping and Exclusive Conceptual Elements

The respective numbers of overlapping and exclusive conceptual elements perceived in the mass-weight concept ranged from 0 to 11 and 10 to 31 for the Worthington student group and from 0 to 11 and 11 to 59 for the Taiwan student group. Tabulated results by student are shown in Table 15.

Figure 7 shows frequency distributions of overlapping and exclusive conceptual elements perceived in mass and weight by the Worthington and Taiwan student groups. The modes for both groups fell in the range from 0 to 9 in the overlapping conceptual element category and in the range from 20 to 29 in the exclusive conceptual element category.

TABLE 14

ADDITIONAL AND DELETED CONCEPTUAL ELEMENTS BY STUDENTS

Worthington			Taiwan		
Student ID Number	Number of Additional Elements	Number of Deleted Elements	Student ID Number	Number of Additional Elements	Number of Deleted Elements
001	2	4	101	9	1
002	2	11	102	2	1
003	4	2	103	11	16
004	2	12	104	5	4
005	0	1	105	20	2
006	0	0	106	0	0
007	2	7	107	12	20
008	7	0	108	4	6
009	1	0	109	2	1
010	0	6	110	12	0
011	2	24	111	6	3
012	4	20	112	4	6
013	0	9	113	0	3
014	1	5	114	13	0
015	3	6	115	7	33
016	1	0	116	0	0
017	0	1	117	1	2
018	1	1	118	1	8
019	6	17	119	4	18

Figure 6

Frequency Distributions of Additional and Deleted Conceptual Elements Perceived in Mass and Weight by Worthington and Taiwan Student Groups

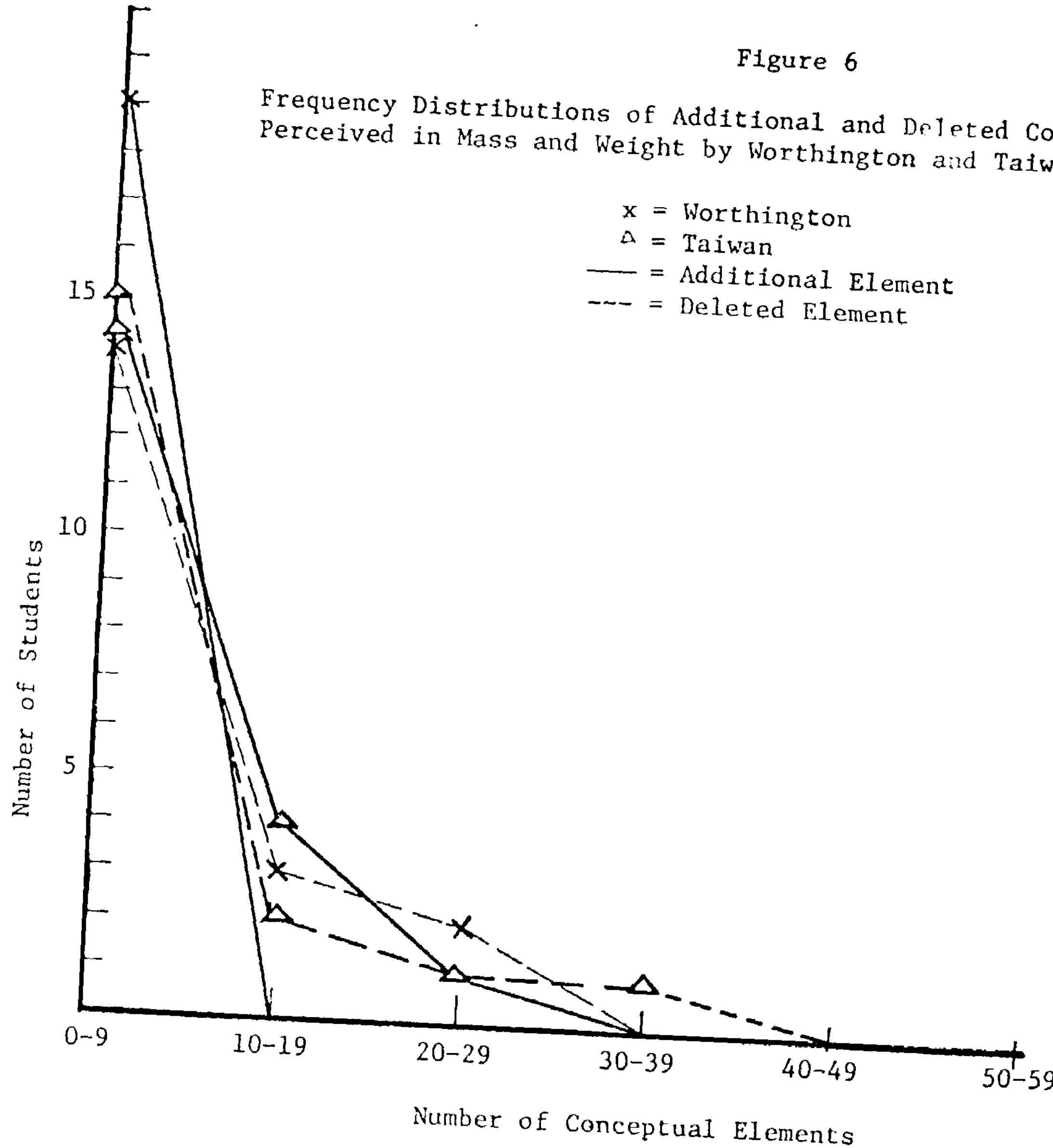


TABLE 15

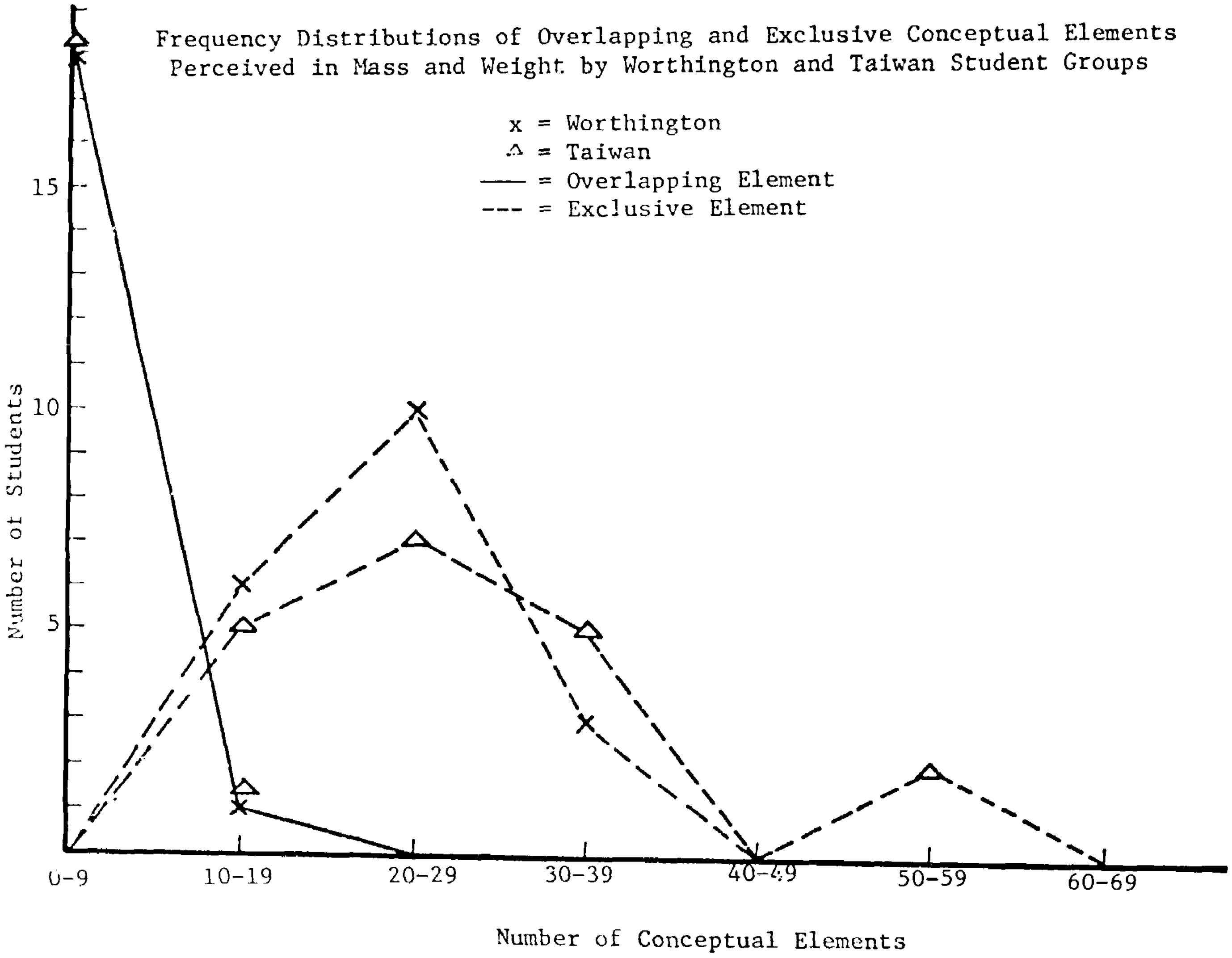
OVERLAPPING AND EXCLUSIVE CONCEPTUAL ELEMENTS BY STUDENTS

Worthington			Taiwan		
Student ID Number	Number of Overlapping Elements	Number of Exclusive Elements	Student ID Number	Number of Overlapping Elements	Number of Exclusive Elements
001	0	11	101	3	30
002	5	24	102	1	31
003	2	20	103	5	35
004	1	12	104	1	17
005	3	10	105	3	33
006	2	28	106	3	28
007	9	12	107	4	27
008	11	16	108	6	50
009	1	25	109	0	25
010	4	12	110	4	27
011	1	24	111	11	59
012	9	20	112	7	18
013	5	27	113	3	29
014	4	20	114	6	37
015	3	31	115	1	11
016	6	25	116	5	16
017	5	30	117	5	22
018	4	30	118	6	20
019	2	24	119	5	13

Figure 7

Frequency Distributions of Overlapping and Exclusive Conceptual Elements Perceived in Mass and Weight by Worthington and Taiwan Student Groups

x = Worthington
Δ = Taiwan
—— = Overlapping Element
--- = Exclusive Element



Number of Correct and Incorrect Uses of Conceptual Elements

The number of correct and incorrect uses of conceptual elements perceived in mass and weight in the solution of the problem set differed from group to group and from subgroup to subgroup. The respective ranges of correct and incorrect uses were from 0 to 104 and 26 to 102 for the Worthington student group and from 8 to 194 and 4 to 106 for the Taiwan student group. A breakdown by student is shown in Table 16.

Figure 8 shows frequency distributions of correct and incorrect uses of conceptual elements perceived in mass and weight by the Worthington and Taiwan student groups. Bi-modal patterns were found in the frequency distributions of correct and incorrect uses of conceptual elements for the Taiwan student group. The modes for both Worthington and Taiwan groups fell in the range from 0 to 39 conceptual elements in both the correct use and incorrect use categories.

The differences between the number of correct and incorrect uses of conceptual elements perceived in the mass-weight concept by the students in their solution of the problem set are shown in Table 17. The ranges were from -66 to 27 for the Worthington student group and from -78 to 148 for the Taiwan student group.

Frequency distributions of differences between the number of correct and incorrect uses of conceptual elements perceived in mass and weight by the Worthington and Taiwan student groups are shown in Figure 9. The modes were found to fall in the range from 0 to 19 conceptual elements for both groups.

TABLE 16

NUMBER OF CORRECT AND INCORRECT USES OF CONCEPTUAL ELEMENTS BY STUDENTS

Worthington			Taiwan		
Student ID Number	Correct Use	Incorrect Use	Student ID Number	Correct Use	Incorrect Use
001	24	43	101	19	10
002	104	87	102	62	38
003	48	34	103	64	46
004	0	51	104	13	4
005	14	39	105	14	19
006	41	60	106	48	52
007	31	48	107	52	32
008	14	56	108	194	46
009	47	28	109	41	24
010	74	62	110	36	4
011	8	32	111	158	93
012	29	44	112	28	106
013	35	64	113	22	15
014	66	102	114	48	12
015	13	51	115	8	22
016	28	94	116	46	44
017	53	26	117	65	14
018	49	102	118	27	45
019	38	29	119	13	15

Figure 8

Frequency Distributions of Correct and Incorrect Uses of Conceptual Elements Perceived in Mass and Weight by Worthington and Taiwan Student Groups

x = Worthington
Δ = Taiwan
—— = Correct Uses
--- = Incorrect Uses

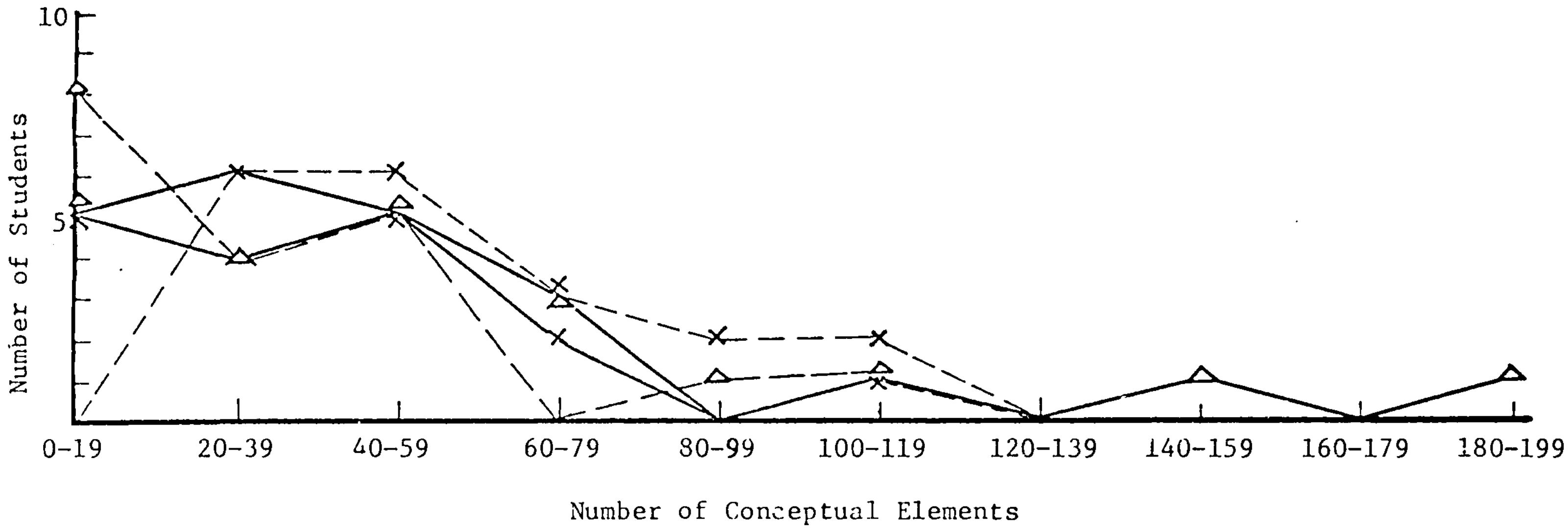


TABLE 17

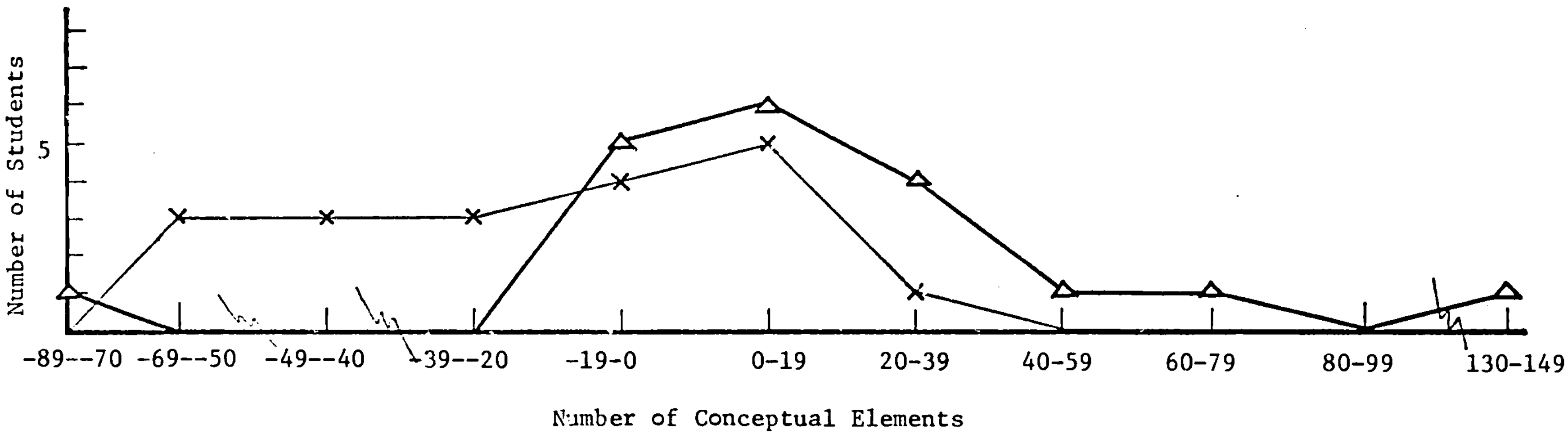
DIFFERENCES BETWEEN NUMBER OF CORRECT AND INCORRECT USES OF CONCEPTUAL ELEMENTS BY STUDENTS

Worthington		Taiwan	
Student ID Number	Difference	Student ID Number	Difference
001	-19	101	9
002	17	102	24
003	14	103	18
004	-51	104	9
005	-25	105	- 5
006	-19	106	- 4
007	-17	107	20
008	-42	108	148
009	19	109	17
010	12	110	32
011	-24	111	65
012	-15	112	-78
013	-29	113	7
014	-36	114	36
015	-38	115	-14
016	-66	116	2
017	27	117	51
018	-53	118	-18
019	9	119	- 2

Figure 9

Frequency Distributions of Differences Between Number of Correct and Incorrect Uses of Conceptual Elements Perceived in Mass and Weight by Worthington and Taiwan Student Groups

x = Worthington
△ = Taiwan



The number of correct uses of conceptual elements perceived in mass or weight to solve the problem set were also tabulated for each subgroup of students to determine correlation matrices between the conceptual elements of mass or weight. Matrix data thus obtained served as the basis for hypothetical tests of cluster analysis. A breakdown by physics concept, student subgroup, and conceptual element is shown in Tables 18, 19, 20, 21, 22, 23, 24, and 25.

Data for the Worthington group's correct uses of conceptual elements perceived in mass or weight to solve the problem set were produced by combining data listed in Tables 18 and 19 or Tables 20 and 21. The same procedures were applied to yield data for the Taiwan group. The four sets of data thus obtained were used in pairs as basis for hypothetical tests of cluster analysis for the Worthington or Taiwan student group.

Importance of Problem-related and Problem-nonrelated Conceptual Elements

The importance indices of conceptual elements were calculated using the method described in Chapter III. The indices of problem-related conceptual elements perceived in the mass-weight concept were found to be higher than those of problem-nonrelated conceptual elements for both Worthington and Taiwan student groups. The respective ranges of problem-related and problem-nonrelated conceptual elements were from 0.455 to 0.994 and 0.006 to 0.545 for the Worthington student group and from 0.469 to 1 and 0 to 0.531 for the Taiwan student group. A breakdown by student is shown in Table 26.

TABLE 18

NUMBER OF CORRECT USES OF CONCEPTUAL ELEMENTS PERCEIVED IN MASS BY WORTHINGTON HIGH-ACHIEVING STUDENTS, AND CONCEPTUAL ELEMENT

Item Number	Student ID Number									
	001	002	003	007	009	010	014	017	019	Total
PMW01	3	6	7	5	5	7	5	5	6	49
PMW02	0	6	0	2	6	7	5	0	0	26
PMW03	0	0	1	2	1	1	0	2	2	9
PMW04	0	6	0	0	6	0	4	2	0	18
PMW05	0	1	0	0	0	0	0	2	4	7
PMW06	3	0	2	0	0	0	1	0	0	6
PMW07	3	0	5	0	0	3	1	0	0	12
PMW08	3	3	0	1	1	0	2	2	0	12
PMW09	0	0	4	0	4	2	0	0	0	10
PMW10	0	1	0	0	0	0	0	0	3	4
PMW11	0	0	0	1	0	0	0	0	1	2
PMW12	0	1	1	0	0	0	0	0	0	2
PMW13	0	0	0	0	0	0	0	0	0	0
PMW14	0	0	0	0	0	0	0	3	0	3
PMW15	0	0	1	0	2	0	0	1	0	4
PMW16	0	0	0	0	1	0	0	1	0	2
PMW17	0	0	0	0	0	7	0	0	0	7
PMW18	0	0	0	0	1	0	1	0	0	2
PMW19	0	0	0	0	0	0	0	0	1	1
PMW20	0	0	0	0	1	0	0	0	1	2
PMW21	0	1	1	0	0	0	0	0	0	2
PMW22	0	1	1	0	0	0	0	0	0	2
PMW23	0	0	0	0	0	0	0	0	0	0
PMW24	0	0	0	0	0	0	0	0	0	0
PMW25	0	0	0	0	0	0	0	0	4	4
PMW26	0	0	0	0	0	0	1	0	0	1
PMW27	0	0	0	0	0	0	0	0	0	0
PMW28	0	3	0	0	0	0	0	0	0	3
PMW29	0	0	0	0	0	0	0	0	0	0
PMW30	0	0	7	1	0	0	5	0	0	13
PMW31	0	7	0	0	0	0	0	0	0	7
PMW32	0	0	0	0	0	0	1	0	0	1
PMW33	0	0	4	0	0	0	0	0	0	4
PMW34	0	0	0	0	0	0	0	2	0	2
PMW35	1	0	0	0	0	5	0	5	0	11
PMW36	0	0	0	0	0	0	0	2	0	2
PMW37	0	0	0	0	7	0	0	0	0	7
PMW38	0	0	0	0	0	0	3	0	0	3
PMW39	0	0	3	0	0	0	0	0	0	3
PMW40	0	0	0	0	0	0	0	0	0	0

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Table 18. (Continued)

Item Number	Student ID Number									
	001	002	003	007	009	010	014	017	019	Total
PMW41	0	0	0	0	0	0	0	0	0	0
PMW42	0	0	0	0	0	0	0	2	0	2
PMW43	0	0	0	0	0	0	0	0	0	0
PMW44	0	0	0	3	0	0	0	0	0	3
PMW45	0	0	0	0	0	0	0	2	0	2
PMW46	0	0	0	0	0	0	0	0	0	0
PMW47	0	0	0	0	0	0	0	0	0	0
PMW48	0	0	0	0	0	0	0	0	0	0
PMW49	0	3	0	0	0	0	0	0	0	3
PMW50	0	0	0	0	0	0	0	0	0	0
PMW51	0	0	0	0	0	0	0	0	0	0
PMW52	0	0	0	0	0	0	0	0	0	0
PMW53	0	1	0	0	0	0	0	0	0	1
PMW54	0	0	0	0	0	0	0	0	0	0
PMW55	1	0	0	0	0	0	0	1	0	2
PMW56	0	0	1	0	0	0	0	0	0	1
Total	14	40	38	15	35	32	29	32	22	257

TABLE 19

NUMBER OF CORRECT USES OF CONCEPTUAL ELEMENTS PERCEIVED IN MASS BY WORTHINGTON LOW-ACHIEVING STUDENTS, AND CONCEPTUAL ELEMENT

Item Number	Student ID Number										
	004	005	006	008	011	012	013	015	016	018	Total
PMW01	0	2	4	2	4	4	0	1	3	4	24
PMW02	0	3	1	0	0	2	4	0	1	0	11
PMW03	0	0	0	0	0	1	1	0	1	1	4
PMW04	0	0	3	0	0	0	0	0	1	0	4
PMW05	0	0	0	1	0	0	2	0	0	1	4
PMW06	0	0	0	0	0	0	0	0	0	1	1
PMW07	0	0	0	0	1	0	0	0	0	1	1
PMW08	0	0	0	0	0	0	0	0	0	0	0
PMW09	0	0	0	0	0	0	3	0	0	4	7
PMW10	0	0	0	0	0	1	2	0	2	1	6
PMW11	0	0	0	0	0	0	1	0	0	0	1
PMW12	0	0	0	0	0	0	0	0	0	1	1
PMW13	0	0	0	0	0	0	0	1	0	0	1
PMW14	0	0	0	0	0	0	0	2	0	0	2
PMW15	0	0	0	0	0	0	0	0	0	0	0
PMW16	0	0	0	0	0	0	4	1	0	0	5
PMW17	0	0	4	0	0	0	4	0	4	0	12
PMW18	0	0	0	0	0	0	2	0	1	0	3
PMW19	0	0	0	0	0	1	0	1	0	0	2
PMW20	0	0	0	0	0	0	0	0	0	0	0
PMW21	0	0	0	0	0	0	0	0	0	0	0
PMW22	0	0	0	0	0	0	0	0	0	0	0
PMW23	0	0	0	0	0	0	2	0	0	0	2
PMW24	0	0	1	0	0	0	2	0	0	0	3
PMW25	0	0	0	0	0	0	0	1	0	1	2
PMW26	0	0	0	0	0	0	0	0	0	0	0
PMW27	0	0	0	4	0	0	0	0	0	0	4
PMW28	0	0	0	0	0	0	0	0	0	0	0
PMW29	0	0	0	1	0	0	0	0	0	0	1
PMW30	0	0	4	0	0	0	0	0	0	0	4
PMW31	0	0	0	0	0	0	4	0	0	2	6
PMW32	0	0	0	0	0	0	0	0	0	0	0
PMW33	0	0	0	0	0	0	0	1	0	0	1
PMW34	0	0	0	0	0	0	0	0	0	0	0
PMW35	0	0	0	0	0	0	0	0	0	0	0
PMW36	0	0	0	0	0	0	1	0	0	0	1
PMW37	0	0	0	0	0	0	0	0	0	0	0

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Table 19. (Continued)

Item Number	Student ID Number									
	004	005	006	008	011	012	013	015	016	018	Total
PMW38	0	0	0	0	0	0	0	0	0	0	0
PMW39	0	0	0	0	0	0	0	0	0	0	0
PMW40	0	0	2	0	0	0	0	0	0	0	2
PMW41	0	0	0	0	0	0	0	0	0	2	2
PMW42	0	0	0	0	0	0	0	0	0	0	0
PMW43	0	0	0	0	0	0	0	0	1	0	1
PMW44	0	0	0	0	0	0	0	0	0	0	0
PMW45	0	0	0	0	0	0	0	0	0	0	0
PMW46	0	0	0	1	0	0	0	0	0	0	1
PMW47	0	0	0	0	0	0	0	0	0	4	4
PMW48	0	1	0	0	0	0	0	0	0	0	1
PMW49	0	0	0	0	0	0	0	0	0	0	0
PMW50	0	0	0	0	0	2	0	0	0	0	2
PMW51	0	0	0	0	0	0	3	0	C	0	3
PMW52	0	0	0	0	0	0	4	0	0	0	4
PMW53	0	0	0	0	0	0	0	0	0	0	0
PMW54	0	0	0	0	0	0	0	0	1	0	1
PMW55	0	0	0	0	0	0	0	0	0	0	0
PMW56	0	0	0	0	0	0	0	0	0	0	0
Total	0	6	19	9	4	15	35	8	15	23	134

TABLE 20

NUMBER OF CORRECT USES OF CONCEPTUAL ELEMENTS PERCEIVED IN WEIGHT BY WORTHINGTON HIGH-ACHIEVING STUDENTS, AND CONCEPTUAL ELEMENT

Item Number	Student ID Number									
	001	002	003	007	009	010	014	017	019	Total
PWW01	4	7	4	3	5	2	5	0	0	30
PWW02	6	6	2	2	6	7	5	5	0	39
PWW03	0	1	0	0	1	2	2	0	3	9
PWW04	0	0	0	0	0	2	0	1	5	8
PWW05	0	1	0	0	0	0	0	0	3	4
PWW06	0	6	2	0	0	4	0	0	0	12
PWW07	0	4	0	0	0	5	0	1	0	10
PWW08	0	0	0	0	0	3	4	6	0	13
PWW09	0	0	0	2	0	1	0	0	0	3
PWW10	0	0	0	0	0	0	4	2	0	6
PWW11	0	4	2	0	0	0	0	0	0	6
PWW12	0	0	0	0	0	0	0	1	0	1
PWW13	0	3	0	0	0	2	0	0	3	8
PWW14	0	2	0	0	0	5	0	0	0	7
PWW15	0	2	0	0	0	4	1	0	2	9
PWW16	0	6	0	0	0	0	0	5	0	11
PWW17	0	7	0	0	0	0	0	0	0	7
PWW18	0	0	0	1	0	0	2	0	0	3
PWW19	0	1	0	0	0	0	0	0	0	1
PWW20	0	0	0	0	0	0	0	0	0	0
PWW21	0	0	0	0	0	5	3	0	0	8
PWW22	0	0	0	0	0	0	0	0	0	0
PWW23	0	0	0	0	0	0	0	0	0	0
PWW24	0	4	0	0	0	0	0	0	0	4
PWW25	0	0	0	0	0	0	0	0	0	0
PWW26	0	0	0	0	0	0	5	0	0	5
PWW27	0	0	0	0	0	0	0	0	0	0
PWW28	0	0	0	0	0	0	0	0	0	0
PWW29	0	5	0	0	0	0	0	0	0	5
PWW30	0	0	0	2	0	0	0	0	0	2
PWW31	0	0	0	3	0	0	0	0	0	3
PWW32	0	0	0	0	0	0	0	0	0	0
PWW33	0	0	0	0	0	0	0	0	0	0
PWW34	0	0	0	1	0	0	0	0	0	1
PWW35	0	0	0	0	0	0	4	0	0	4
PWW36	0	0	0	0	0	0	0	0	0	0
PWW37	0	0	0	0	0	0	2	0	0	2

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Table 20. (Continued)

Item Number	Student ID Number									
	001	002	003	007	009	010	014	017	019	Total
PWW38	0	0	0	0	0	0	0	0	0	0
PWW39	0	2	0	0	0	0	0	0	0	2
PWW40	0	0	0	2	0	0	0	0	0	2
PWW41	0	0	0	0	0	0	0	0	0	0
PWW42	0	0	0	0	0	0	0	0	0	0
PWW43	0	3	0	0	0	0	0	0	0	3
Total	10	64	10	16	12	42	37	21	16	228

TABLE 21

NUMBER OF CORRECT USES OF CONCEPTUAL ELEMENTS PERCEIVED IN WEIGHT BY WORTHINGTON LOW-ACHIEVING STUDENTS, AND CONCEPTUAL ELEMENT

Item Number	Student ID Number 004	005	006	008	011	012	013	015	016	018	Total
PWW01	0	0	4	3	3	4	0	3	0	3	20
PWW02	0	3	2	0	0	2	0	0	2	4	13
PWW03	0	1	0	0	0	1	0	1	3	4	10
PWW04	0	0	0	0	0	0	0	1	0	0	1
PWW05	0	1	0	0	0	0	0	0	0	4	5
PWW06	0	0	4	0	0	0	0	0	0	1	5
PWW07	0	0	0	0	0	0	0	0	2	0	2
PWW08	0	0	4	0	0	0	0	0	0	1	5
PWW09	0	0	0	0	1	1	0	0	0	0	2
PWW10	0	0	0	0	0	0	0	0	0	2	2
PWW11	0	0	2	0	0	0	0	0	0	0	2
PWW12	0	0	0	0	0	0	0	0	0	0	0
PWW13	0	0	0	0	0	0	0	0	0	0	0
PWW14	0	0	0	0	0	0	0	0	2	0	2
PWW15	0	0	0	0	0	0	0	0	0	0	0
PWW16	0	0	4	0	0	2	0	0	0	0	6
PWW17	0	0	0	0	0	0	0	0	3	0	3
PWW18	0	0	0	0	0	0	0	0	0	0	0
PWW19	0	0	0	0	0	0	0	0	0	0	0
PWW20	0	0	0	0	0	0	0	0	0	1	1
PWW21	0	0	0	0	0	0	0	0	0	0	0
PWW22	0	0	0	0	0	0	0	0	0	2	2
PWW23	0	0	0	0	0	0	0	0	1	0	1
PWW24	0	0	2	0	0	0	0	0	0	0	2
PWW25	0	0	0	1	0	0	0	0	0	0	0
PWW26	0	0	0	0	0	0	0	0	0	0	0
PWW27	0	3	0	0	0	0	0	0	0	0	3
PWW28	0	0	0	0	0	0	0	0	0	3	3
PWW29	0	0	0	0	0	0	0	0	0	0	0
PWW30	0	0	0	0	0	0	0	0	0	0	0
PWW31	0	0	0	0	0	0	0	0	0	0	0
PWW32	0	0	0	1	0	0	0	0	0	0	1
PWW33	0	0	0	0	0	1	0	0	0	0	1
PWW34	0	0	0	0	0	0	0	0	0	0	0
PWW35	0	0	0	0	0	0	0	0	0	0	0
PWW36	0	0	0	0	0	1	0	0	0	0	1
PWW37	0	0	0	0	0	0	0	0	0	0	0

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Table 21. (Continued)

Item Number	Student ID Number										
	004	005	006	008	011	012	013	015	016	018	Total
PWW38	0	0	0	0	0	0	0	0	0	1	1
PWW39	0	0	0	0	0	0	0	0	0	0	0
PWW40	0	0	0	0	0	0	0	0	0	0	0
PWW41	0	0	0	0	0	1	0	0	0	0	1
PWW42	0	0	0	0	0	1	0	0	0	0	1
PWW43	0	0	0	0	0	0	0	0	0	0	0
Total	0	8	22	5	4	14	0	5	13	26	97

TABLE 22

NUMBER OF CORRECT USES OF CONCEPTUAL ELEMENTS PERCEIVED IN MASS BY TAIWAN HIGH-ACHIEVING STUDENTS, AND CONCEPTUAL ELEMENT

Item Number	Student ID Number									
	101	104	107	108	109	110	114	117	118	Total
PMT01	0	0	0	10	5	6	1	2	6	30
PMT02	2	0	1	10	1	2	0	8	4	28
PMT03	0	0	0	3	0	1	1	0	0	5
PMT04	1	0	1	1	1	0	0	2	0	6
PMT05	0	0	0	10	4	1	0	0	0	15
PMT06	1	1	2	6	3	6	0	0	0	19
PMT07	1	0	0	0	0	0	1	4	0	6
PMT08	0	1	6	2	0	0	1	4	0	14
PMT09	1	0	0	0	1	0	1	0	0	3
PMT10	0	0	3	10	0	2	0	0	2	17
PMT11	0	0	0	0	0	0	0	6	0	6
PMT12	0	0	0	5	2	1	0	0	0	8
PMT13	0	0	0	1	0	1	1	0	1	4
PMT14	0	0	2	8	0	0	0	4	0	14
PMT15	0	1	3	0	0	0	3	0	0	7
PMT16	1	1	0	5	0	0	0	0	0	7
PMT17	0	0	7	0	0	0	0	0	0	17
PMT18	0	0	0	5	0	0	4	0	0	9
PMT19	0	0	0	0	0	0	0	0	0	0
PMT20	0	0	0	0	0	0	0	0	0	0
PMT21	0	0	0	0	0	0	0	0	0	0
PMT22	0	0	0	0	0	1	0	0	0	1
PMT23	0	0	0	7	0	0	0	0	0	7
PMT24	0	0	0	0	1	0	0	0	0	1
PMT25	0	0	0	7	0	0	0	0	0	7
PMT26	0	0	0	0	0	0	1	0	2	3
PMT27	0	0	0	0	0	0	0	0	0	0
PMT28	2	0	0	4	0	0	0	0	0	6
PMT29	0	0	0	0	0	0	0	0	0	0
PMT30	0	0	0	0	0	0	0	0	0	0
PMT31	0	0	0	0	0	0	0	0	0	0
PMT32	0	0	1	2	0	0	0	0	0	3
PMT33	0	0	0	0	0	0	0	0	0	0
PMT34	0	0	0	0	0	1	0	0	0	1
PMT35	0	0	1	0	0	0	0	0	0	1
PMT36	0	0	0	0	0	0	1	0	0	1
PMT37	0	0	0	0	0	0	0	0	0	0

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Table 22. (Continued)

Item Number	Student ID Number 101	104	107	108	109	110	114	117	118	Total
PMT38	0	0	0	0	0	0	0	0	0	0
PMT39	0	0	0	7	0	0	0	1	0	8
PMT40	0	0	0	0	0	0	0	0	0	0
PMT41	0	0	0	0	0	0	0	0	0	0
PMT42	0	0	0	0	0	0	0	0	0	0
PMT43	0	0	0	0	0	0	0	2	0	2
PMT44	0	0	0	0	0	0	0	0	0	0
PMT45	0	0	0	0	0	0	0	0	0	0
PMT46	0	0	0	0	0	0	0	0	0	0
PMT47	0	0	0	0	0	0	0	0	0	0
PMT48	0	0	0	0	0	1	0	0	0	1
PMT49	0	0	0	0	0	0	0	0	0	0
PMT50	0	0	0	0	0	0	0	0	0	0
PMT51	0	0	0	0	0	0	0	0	0	0
PMT52	0	0	0	0	0	0	1	0	0	1
PMT53	0	0	0	0	0	1	0	0	0	1
PMT54	0	0	0	0	0	0	0	0	0	0
PMT55	0	0	0	0	0	0	0	0	2	2
PMT56	0	0	0	0	0	0	0	0	0	0
PMT57	0	0	0	0	0	0	0	1	0	1
PMT58	0	0	0	0	0	0	0	0	0	0
PMT59	0	0	0	0	0	0	0	0	0	0
PMT60	0	0	0	0	0	0	0	0	0	0
PMT61	0	0	0	0	0	1	0	0	0	1
PMT62	0	0	0	0	0	1	0	0	0	1
PMT63	0	0	0	0	0	0	0	1	0	1
PMT64	0	0	0	0	0	0	0	0	0	0
PMT65	0	0	0	0	0	0	0	0	0	0
PMT66	0	0	0	0	0	0	1	0	0	1
Total	9	4	27	113	18	26	17	35	17	266

TABLE 23

NUMBER OF CORRECT USES OF CONCEPTUAL ELEMENTS PERCEIVED IN MASS BY TAIWAN LOW-ACHIEVING STUDENTS, AND CONCEPTUAL ELEMENT

Item Number	Student ID Number										
	102	103	105	106	111	112	113	115	116	119	Total
PMT01	0	0	1	5	7	3	6	2	3	0	27
PMT02	0	5	2	0	6	3	0	0	4	1	21
PMT03	1	0	0	0	0	0	0	0	5	0	6
PMT04	2	1	0	2	1	2	0	0	0	1	9
PMT05	0	0	5	3	7	0	0	0	1	0	16
PMT06	4	0	0	0	0	0	1	0	0	0	5
PMT07	0	1	0	0	2	0	0	0	0	0	3
PMT08	0	1	0	0	6	1	0	0	0	0	8
PMT09	1	0	1	0	1	0	0	0	1	0	4
PMT10	0	0	0	0	5	0	1	0	0	0	6
PMT11	0	1	0	0	6	2	0	0	0	2	11
PMT12	4	0	0	0	0	0	0	0	0	0	4
PMT13	1	0	0	0	0	2	0	0	0	0	3
PMT14	5	1	0	2	0	0	0	0	0	0	8
PMT15	2	0	0	0	0	0	0	0	0	0	2
PMT16	0	0	0	0	0	0	0	0	0	0	0
PMT17	0	6	0	0	7	0	0	0	0	0	13
PMT18	0	1	0	0	5	0	0	0	0	0	6
PMT19	1	1	0	1	0	0	0	0	0	0	3
PMT20	1	0	0	0	0	0	0	0	0	0	1
PMT21	0	0	0	0	6	1	0	0	0	0	7
PMT22	0	0	1	0	0	0	0	0	0	0	1
PMT23	0	4	0	0	5	0	0	0	0	0	9
PMT24	0	0	1	0	0	0	0	0	2	0	3
PMT25	0	0	0	0	0	0	0	0	0	0	0
PMT26	0	0	0	0	0	0	0	0	0	0	0
PMT27	0	0	0	2	4	1	0	0	0	0	7
PMT28	0	0	0	0	0	0	0	0	0	2	2
PMT29	0	0	0	0	0	1	0	0	0	0	1
PMT30	0	0	0	0	0	0	0	0	1	0	1
PMT31	0	0	0	1	0	0	0	0	0	0	1
PMT32	0	0	1	0	0	0	0	0	0	0	1
PMT33	0	0	0	0	0	0	0	1	0	0	1
PMT34	0	0	0	0	0	0	0	1	0	0	1
PMT35	0	0	0	0	0	0	0	0	0	0	0
PMT36	0	0	0	0	0	0	0	0	0	0	0
PMT37	0	0	0	0	2	0	0	0	0	0	2

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Table 23. (Continued)

Item Number	Student ID Number										
	102	103	105	106	111	112	113	115	116	119	Total
PMT38	0	0	1	0	0	0	0	0	0	0	1
PMT39	0	1	0	0	0	0	0	0	0	0	1
PMT40	0	0	0	0	4	0	0	0	0	0	4
PMT41	0	0	0	0	7	0	0	0	0	0	7
PMT42	0	0	0	0	7	0	0	0	0	0	7
PMT43	0	1	0	0	0	0	0	0	0	0	1
PMT44	0	0	0	3	0	0	0	0	0	0	3
PMT45	0	0	1	0	0	0	0	0	0	0	1
PMT46	0	0	0	1	0	0	0	0	0	0	1
PMT47	0	0	0	3	0	0	0	0	0	0	3
PMT48	0	0	0	0	0	0	0	0	0	0	0
PMT49	0	3	0	0	0	0	0	0	0	0	3
PMT50	0	0	0	0	6	0	0	0	0	0	6
PMT51	0	0	0	0	1	0	0	0	0	0	1
PMT52	0	0	0	0	0	0	0	0	0	0	0
PMT53	0	0	0	0	0	0	0	0	0	0	0
PMT54	0	0	0	0	0	0	0	0	0	2	2
PMT55	0	0	0	0	2	0	0	0	0	0	2
PMT56	0	0	0	0	2	0	0	0	0	0	2
PMT57	0	0	0	0	0	0	0	0	2	0	2
PMT58	0	1	0	0	0	0	0	0	0	0	1
PMT59	0	0	0	0	1	0	0	0	0	0	1
PMT60	0	0	0	0	1	0	0	0	0	0	1
PMT61	0	0	0	0	0	0	0	0	0	0	0
PMT62	0	0	0	0	0	0	0	0	0	0	0
PMT63	0	0	0	0	0	0	0	0	0	0	0
PMT64	0	0	0	0	0	0	0	0	1	0	1
PMT65	0	0	0	1	0	0	0	0	0	0	1
PMT66	0	0	0	0	0	0	0	0	0	0	0
Total	22	28	14	24	101	16	8	4	20	8	245

TABLE 24

NUMBER OF CORRECT USES OF CONCEPTUAL ELEMENTS PERCEIVED IN WEIGHT BY TAIWAN HIGH-ACHIEVING STUDENTS, AND CONCEPTUAL ELEMENT

Item Number	Student ID Number 101	104	107	108	109	110	114	117	118	Total
PWT01	0	0	0	10	4	0	0	0	1	15
PWT02	1	1	2	1	1	2	2	0	5	15
PWT03	0	0	2	0	6	0	3	0	4	15
PWT04	1	0	0	6	0	0	0	3	0	10
PWT05	1	0	2	0	0	2	2	0	0	7
PWT06	1	0	0	0	0	0	3	0	0	4
PWT07	0	0	1	4	0	0	2	0	0	7
PWT08	0	0	2	9	1	0	0	0	0	12
PWT09	0	0	4	9	3	0	2	5	0	23
PWT10	0	0	0	10	0	2	9	1	0	22
PWT11	1	0	0	0	0	0	3	0	0	4
PWT12	0	0	0	0	0	0	0	0	0	0
PWT13	0	0	1	0	0	0	0	0	0	1
PWT14	0	0	2	0	0	0	0	1	0	3
PWT15	0	1	0	0	0	0	3	0	0	4
PWT16	0	0	0	8	0	0	0	2	0	10
PWT17	0	1	0	0	0	0	0	0	0	1
PWT18	0	1	2	0	0	0	0	0	0	3
PWT19	0	2	0	2	0	0	0	0	0	4
PWT20	0	0	0	0	0	0	0	0	0	0
PWT21	0	0	1	0	4	0	0	0	0	5
PWT22	0	0	0	0	0	0	0	1	0	1
PWT23	0	0	1	0	0	0	0	5	0	6
PWT24	2	2	0	0	1	0	0	0	0	5
PWT25	0	0	0	1	0	0	0	0	0	1
PWT26	0	0	2	0	0	2	0	0	0	4
PWT27	1	0	0	0	0	0	0	4	0	5
PWT28	0	0	0	10	0	0	0	0	0	10
PWT29	0	0	0	2	0	0	0	0	0	2
PWT30	1	0	0	0	0	0	0	0	0	1
PWT31	0	0	0	0	0	0	0	0	0	0
PWT32	0	0	0	2	0	0	0	0	0	2
PWT33	0	0	0	0	0	0	0	0	0	0
PWT34	0	0	0	0	1	0	2	0	0	3
PWT35	0	0	1	0	0	0	0	2	0	3
PWT36	0	1	0	0	0	0	0	0	0	1
PWT37	0	0	0	0	1	0	0	0	0	1

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Table 24. (Continued)

Item Number	Student ID Number									
	101	104	107	108	109	110	114	117	118	Total
PWT38	0	0	0	0	0	0	0	0	0	0
PWT39	0	0	0	1	0	0	0	0	0	1
PWT40	0	0	0	4	0	0	0	0	0	4
PWT41	0	0	0	0	0	0	0	0	0	0
PWT42	0	0	0	0	0	0	0	0	0	0
PWT43	0	0	0	0	0	0	0	0	0	0
PWT44	0	0	0	0	0	0	0	6	0	6
PWT45	0	0	0	0	0	0	0	0	0	0
PWT46	0	0	1	0	1	0	0	0	0	2
PWT47	0	0	0	0	0	0	0	0	0	0
PWT48	1	0	0	0	0	0	0	0	0	1
PWT49	0	0	0	0	0	0	0	0	0	0
PWT50	0	0	0	0	0	0	0	0	0	0
PWT51	0	0	0	0	0	0	0	0	0	0
PWT52	0	0	0	0	0	2	0	0	0	2
PWT53	0	0	0	0	0	0	0	0	0	0
PWT54	0	0	1	0	0	0	0	0	0	1
PWT55	0	0	0	0	0	0	0	0	0	0
PWT56	0	0	0	2	0	0	0	0	0	2
PWT57	0	0	0	0	0	0	0	0	0	0
Total	10	9	25	81	23	10	31	30	10	229

TABLE 25

NUMBER OF CORRECT USES OF CONCEPTUAL ELEMENTS PERCEIVED IN WEIGHT BY TAIWAN LOW-ACHIEVING STUDENTS, AND CONCEPTUAL ELEMENT

Item Number	Student ID Number										
	102	103	105	106	111	112	113	115	116	119	Total
PWT01	7	6	0	1	4	0	1	2	0	1	22
PWT02	2	1	0	0	0	0	1	0	0	0	4
PWT03	0	2	0	6	4	3	5	0	4	0	24
PWT04	2	1	0	2	0	0	0	0	1	1	7
PWT05	6	0	0	0	3	0	1	0	0	0	10
PWT06	6	2	0	1	0	0	0	0	0	0	9
PWT07	0	2	0	0	5	0	0	0	0	0	7
PWT08	0	1	0	0	5	0	0	0	4	1	11
PWT09	3	0	0	0	0	0	0	0	0	0	3
PWT10	0	0	0	3	0	0	1	0	5	0	9
PWT11	0	1	0	0	2	0	1	0	3	0	7
PWT12	0	0	0	0	3	0	0	0	0	0	3
PWT13	0	2	0	0	0	0	0	1	0	0	3
PWT14	0	0	0	0	3	2	0	0	0	0	5
PWT15	0	0	0	0	0	0	0	0	4	0	4
PWT16	5	0	0	0	0	0	0	0	0	0	5
PWT17	0	1	0	0	1	1	2	0	1	0	6
PWT18	0	6	0	0	0	0	0	0	0	0	6
PWT19	3	0	0	0	0	0	0	0	0	0	3
PWT20	0	6	0	0	2	1	0	0	0	0	9
PWT21	0	0	0	0	0	0	0	0	0	0	0
PWT22	0	0	0	0	1	0	0	0	0	0	1
PWT23	5	0	0	0	0	0	0	0	0	0	5
PWT24	0	2	0	0	0	0	0	0	0	0	2
PWT25	0	0	0	0	0	0	0	0	0	1	1
PWT26	0	0	0	0	0	0	0	0	0	0	0
PWT27	0	0	0	1	1	0	0	0	3	0	5
PWT28	0	0	0	0	0	4	0	0	0	0	4
PWT29	0	0	0	0	1	0	0	1	0	0	2
PWT30	0	0	0	0	2	0	0	0	0	0	2
PWT31	0	2	0	1	0	0	0	0	0	0	3
PWT32	0	0	0	0	0	0	0	0	0	0	0
PWT33	0	1	0	0	0	0	0	0	0	0	1
PWT34	0	0	0	0	0	0	0	0	0	0	0
PWT35	0	0	0	0	0	0	0	0	0	0	0
PWT36	0	0	0	0	0	0	0	0	0	0	0
PWT37	0	0	0	0	0	0	0	0	0	0	0

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Table 25. (Continued)

Item Number	Student ID Number										
	102	103	105	106	111	112	113	115	116	119	Total
PWT38	0	0	0	0	5	0	1	0	0	0	6
PWT39	0	0	0	0	0	0	0	0	0	0	0
PWT40	0	0	0	0	0	0	0	0	0	0	0
PWT41	1	0	0	0	3	0	0	0	0	0	4
PWT42	0	0	0	0	1	0	0	0	0	0	1
PWT43	0	0	0	0	7	0	0	0	0	0	7
PWT44	0	0	0	0	0	0	0	0	0	0	0
PWT45	0	0	0	0	4	0	0	0	0	0	4
PWT46	0	0	0	0	0	0	0	0	0	0	0
PWT47	0	0	0	4	0	0	0	0	0	0	4
PWT48	0	0	0	0	0	0	0	0	0	0	0
PWT49	0	0	0	1	0	0	0	0	0	0	1
PWT50	0	0	0	0	0	0	1	0	0	0	1
PWT51	0	0	0	0	0	0	0	0	0	1	1
PWT52	0	0	0	0	0	0	0	0	0	0	0
PWT53	0	0	0	0	0	0	0	0	1	0	1
PWT54	0	0	0	0	0	0	0	0	0	0	0
PWT55	0	0	0	4	0	0	0	0	0	0	4
PWT56	0	0	0	0	0	0	0	0	0	0	0
PWT57	0	0	0	0	0	1	0	0	0	0	1
Total	40	36	0	24	57	12	14	4	26	5	218

TABLE 26

IMPORTANCE INDICES OF PROBLEM-RELATED AND NONRELATED CONCEPTUAL ELEMENTS BY STUDENTS

Worthington			Taiwan		
Student ID	Problem-Related Conceptual Element	Problem-Nonrelated Conceptual Element	Student ID	Problem-Related Conceptual Element	Problem-Nonrelated Conceptual Element
001	0.966	0.034	101	0.639	0.361
002	0.974	0.026	102	0.772	0.228
003	0.916	0.084	103	0.841	0.159
004	0.896	0.104	104	0.668	0.332
005	0.892	0.108	105	0.469	0.531
006	0.702	0.298	106	0.996	0.004
007	0.864	0.136	107	1.000	0.000
008	0.768	0.232	108	0.753	0.247
009	0.647	0.353	109	0.948	0.052
010	0.994	0.006	110	0.757	0.243
011	0.723	0.277	111	0.822	0.178
012	0.581	0.419	112	0.959	0.041
013	0.455	0.545	113	0.593	0.407
014	0.933	0.067	114	0.695	0.305
015	0.523	0.477	115	0.900	0.100
016	0.845	0.155	116	0.966	0.034
017	0.841	0.159	117	0.994	0.006
018	0.852	0.148	118	0.650	0.350
019	0.777	0.223	119	0.878	0.122

Summary

Tabulation of data and calculation of importance indices of conceptual elements were done in an effort to obtain results suitable for further computer analysis of students' differences. Indeed, even from these tabulated results, students' association behaviors were found to differ to some extent with their cultural background differences. For example, some Worthington High School students associated religious terms with mass and some Taiwan students associated qualitative terms with mass. This reflected differences in the implied semantic meaning of the word "mass" in English and Chinese.

To acquire more decisive information, additional analyses were conducted using the above findings.

Test Item Analysis

The purpose of item analyses of this study was to observe whether the student groups of varying cultural backgrounds responded differently to each of the test items involved in the mass-weight problem set. In this connection, only relative difficulties of test items are reported here.

Item Relative Difficulties

The item analysis package developed by the Center for Measurement and Evaluation of The Ohio State University was used to calculate the relative difficulties of test items. The number of correct answers of an individual student on the mass-weight problem set served as his score. A breakdown of relative difficulties by student group is shown in Table 27.

TABLE 27

ITEM RELATIVE DIFFICULTIES BY STUDENT GROUP

Item	Worthington Student Group	Taiwan Student Group
1	.364	.067
2	.111	.176
3	.333	.176
4	.778	.167
5	.143	.100
6	.353	.333
7	.474	.105
8	.833	.824
9	.789	.947
10	.667	.889
11	.333	.167
12	.824	.389

Summary

The Taiwan student group had more difficulties with test items 2, 9, and 10 than did the Worthington student group. Further analysis of these items indicated that test item 2 was of a classificatory nature, test item 9 involved some ideas of football playing which were not familiar to Taiwan students, and test item 10 was of an inferential nature with a special term "specific gravity" not defined in the PSSC textbook. The origin of the difficulties encountered by Taiwan students would be explainable by cultural differences, especially for items 9 and 10, assuming the relative difficulties to be significantly different between the Worthington and Taiwan student groups.

Analysis of Hypothesis

This section contains a summary of the results obtained from analyses of variance, a restatement of hypotheses, and a statement of support or rejection of hypothesis (.05 level of significance). The sequencing of hypotheses used here is the same as that in Chapter 1.

Test of Significance

The multivariate analysis of variance program distributed by Clyde Computing Service was used to complete multivariate test of significance. The eight variables involved in the test were the importance indices of problem-related conceptual elements, the numbers of correct and incorrect uses of conceptual elements, and the numbers of problem-related, physical science, additional, deleted, and exclusive conceptual elements. The F-value was found to be 4.339 with a probability less than 0.002.

The same program was used to perform a two-way analysis of variance for hypothetical testing of the study. The two factors were student achievement and cultural background. The two levels include high achievement and low achievement in the achievement factor and Worthington and Taiwan in the cultural factor. The results obtained are summarized in Table 28. (For means and standard deviations, see Appendix G.)

Hypotheses Concerning Cultural Backgrounds

1.1 There is no significant difference between the sample groups of varying cultural backgrounds in terms of the total number of conceptual elements elucidated by the students.

Not Rejected: For the total number of conceptual elements there was no significant difference between the Worthington and Taiwan student groups. Both groups paid similar attention to the investigator's word association tests and gave a similar number of elements within a similar time span.

1.2 There is no significant difference between the sample groups of varying cultural backgrounds in terms of the number of problem-related conceptual elements elucidated by the students.

Rejected: For the number of problem-related conceptual elements there was a significant difference between the Worthington and Taiwan student groups. The Taiwan group identified more terms for use in the solution of the problem set than the Worthington group did.

TABLE 28

SUMMARY TABLE OF TWO-WAY ANALYSIS OF VARIANCE FOR STUDENT VARIABLES

Hypothesis	Source	SS	DF	MSS	F	P<
	Total Number of Elements					
1.1	Culture (C)	398.1	1	398.1	2.41	0.13
2.1	Achievement (A)	66.2	1	66.2	2.40	0.53
	C x A	29.5	1	29.5	0.18	0.68
	Within	5611.4	34	165.0		
	Number of Problem-related Elements					
1.2	Culture (C)	404.6	1	404.6	4.38	0.04*
2.2	Achievement (A)	5.8	1	5.8	0.06	0.80
	C x A	33.2	1	33.2	0.36	0.55
	Within	3137.6	34	92.2		
	Number of Problem-nonrelated Elements					
1.3	Culture (C)	0.0	1	0.0	0.00	0.98
2.3	Achievement (A)	111.3	1	111.3	1.81	0.19
	C x A	125.4	1	125.4	2.04	0.16
	Within	2084.1	34	61.3		
	Number of Physical Science Elements					
1.4	Culture (C)	656.9	1	656.9	9.11	0.01*
2.4	Achievement (A)	3.8	1	3.8	0.05	0.82
	C x A	1.8	1	1.8	0.02	0.88
	Within	2451.2	34	72.0		
	Number of Everyday Elements					
1.5	Culture (C)	65.7	1	65.7	1.04	0.31
2.5	Achievement (A)	107.3	1	107.3	1.70	0.20
	C x A	0.0	1	0.0	0.00	0.99
	Within	2136.4	34	62.8		

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Table 28. (Continued)

Hypoth-esis	Source	SS	DF	MSS	F	p<
	Number of Additional Elements					
1.6	Culture (C)	148.0	1	148.0	8.08	0.01*
2.6	Achievement (A)	3.1	1	3.1	0.17	0.68
	C x A	3.1	1	3.1	0.17	0.68
	Within	622.6	34	18.3		
	Number of Deleted Elements					
1.7	Culture (C)	0.1	1	0.1	0.00	0.97
2.7	Achievement (A)	57.9	1	57.9	0.85	0.36
	C x A	10.6	1	10.6	0.15	0.70
	Within	2316.5	34	68.1		
	Importance of Problem-related Elements					
1.8	Culture (C)	0.0	1	0.0	0.02	0.87
2.8	Achievement (A)	0.0	1	0.0	1.65	0.21
	C x A	0.1	1	0.1	3.64	0.07
	Within	0.8	34	0.0		
	Importance of Problem-nonrelated Elements					
1.9	Culture (C)	0.0	1	0.0	0.02	0.87
2.9	Achievement (A)	0.0	1	0.0	1.65	0.21
	C x A	0.1	1	0.1	3.64	0.07
	Within	0.8	34	0.0		
	Number of Overlapping Elements					
1.10	Culture (C)	0.1	1	0.1	0.01	0.91
2.10	Achievement (A)	5.0	1	5.0	0.61	0.44
	C x A	0.4	1	0.4	0.05	0.82
	Within	278.0	34	8.1		

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Table 28. (Continued)

Hypoth-esis	Source	SS	DF	MSS	F	p <
	Number of Exclusive Elements					
1.11	Culture (C)	424.4	1	424.4	4.16	0.05*
2.11	Achievement (A)	5.2	1	5.2	0.05	0.82
	C x A	29.9	1	29.9	0.29	0.59
	Within	3465.7	34	101.9		
	Number of Correct Uses					
1.12	Culture (C)	1528.4	1	1528.4	1.07	0.31
2.12	Achievement (A)	3672.5	1	3672.5	2.57	0.12
	C x A	1167.2	1	1167.2	0.81	0.37
	Within	48480.7	34	1425.9		
	Number of Incorrect Uses					
1.13	Culture (C)	4445.2	1	4445.2	6.90	0.01*
2.13	Achievement (A)	2437.0	1	2437.0	3.78	0.06
	C x A	567.3	1	567.3	0.88	0.36
	Within	21897.6	34	644.0		

* Significant at the .05 level.

1.3 There is no significant difference between the sample groups of varying cultural backgrounds in terms of the number of problem-nonrelated conceptual elements elucidated by the students.

Not rejected: For the number of problem-nonrelated conceptual elements there was no significant difference between the Worthington and Taiwan student groups. Both groups paid similar attention to problem-nonrelated conceptual elements in their association behaviors.

1.4 There is no significant difference between the sample groups of varying cultural backgrounds in terms of the number of physical science conceptual elements elucidated by the students.

Rejected: For the number of physical science conceptual elements there was a significant difference at 0.01 level between the Worthington and Taiwan student groups. Taiwan students' association behaviors seemed to be guided by the textbook or test form whereas Worthington students associated what they considered important with the stimulus words, mass and weight.

1.5 There is no significant difference between the sample groups of varying cultural backgrounds in terms of the number of everyday conceptual elements elucidated by the students.

Not rejected: For the number of everyday conceptual elements there was no significant difference between the Worthington and Taiwan student groups. The number of everyday conceptual elements given by the Worthington group was not significantly different from, but higher than, that of the Taiwan group (see Appendix G).

1.6 There is no significant difference between the sample groups of varying cultural backgrounds in terms of the number of additional conceptual elements elucidated by the students.

Rejected: For the number of additional conceptual elements there was a significant difference between the Worthington and Taiwan student groups. Referring to the test results of hypothesis 1.1, Taiwan students were either more flexible or more dominated by the investigator's mass-weight problem set than were Worthington students. In the latter case, the authority of the test or test administrator was more influential for the Taiwan student group than for the Worthington student group.

1.7 There is no significant difference between the sample groups of varying cultural backgrounds in terms of the number of deleted conceptual elements elucidated by the students.

Not Rejected: For the number of deleted conceptual elements there was no significant difference between the Worthington and Taiwan student groups. Both groups showed the same flexibility in terms of deletion behaviors.

1.8 There is no significant difference between the sample groups of varying cultural backgrounds in terms of the scale of importance of problem-related conceptual elements elucidated by the students.

Not Rejected: For the importance of problem-related conceptual elements there was no significant difference between the Worthington and Taiwan student groups. Both groups perceived problem-related conceptual elements at a higher degree of awareness than they did for problem-nonrelated elements.

1.9 There is no significant difference between the sample groups of varying cultural backgrounds in terms of the scale of importance of problem-nonrelated conceptual elements elucidated by the students.

Not Rejected: For the importance of problem-nonrelated conceptual elements there was no significant difference between the Worthington and Taiwan student groups. Both groups ranked the problem-nonrelated conceptual elements at a lower degree of importance than they did for problem-related conceptual elements.

1.10 There is no significant difference between the sample groups of varying cultural backgrounds in terms of the number of overlapping conceptual elements elucidated by the students.

Not Rejected: For the number of overlapping conceptual elements there was no significant difference between the Worthington and Taiwan student groups. Since the overlapping terms were generally the origin of confusion between two physics concepts, both groups appeared to have a similar background for distinction between mass and weight.

1.11 There is no significant difference between the sample groups of varying cultural backgrounds in terms of the number of exclusive conceptual elements elucidated by the students.

Rejected: For the number of exclusive conceptual elements there was a significant difference between the Worthington and Taiwan student groups. Taiwan students associated more terms with the stimuli, mass and weight, than did Worthington students.

1.12 There is no significant difference between the sample groups of varying cultural backgrounds in terms of the number of correct uses of conceptual elements in the solution of problems.

Not Rejected: For the number of correct uses of problem-related conceptual elements there was no significant difference between the Worthington and Taiwan student groups. Both groups appeared to have the same basis and strategy for correctly answering the mass-weight problem set.

1.13 There is no significant difference between the sample groups of varying cultural backgrounds in terms of the number of incorrect uses of conceptual elements in the solution of problems.

Rejected: For the number of incorrect uses of conceptual elements there was a significant difference between the Worthington and Taiwan student groups. Taiwan students were more conservative in the assignment of a conceptual element to an incorrectly answered item.

Hypotheses Concerning Student Achievement

2.1 There is no significant difference between the high- and low-achieving sample subgroups in terms of the total number of conceptual elements elucidated by the students.

Not Rejected: For the total number of conceptual elements there was no significant difference between the Worthington high- and low-achieving student subgroups and between the Taiwan high- and low-achieving subgroups. During a predetermined period of time, the students gave the associated words at a similar speed.

2.2 There is no significant difference between the high- and low-achieving sample subgroups in terms of the number of problem-related conceptual elements elucidated by the students.

Not Rejected: For the number of problem-related conceptual elements there was no significant difference between the Worthington high- and low-achieving student subgroups. The same was true for the two Taiwan subgroups. Students in a common cultural pattern responded similarly to the stimulus words, mass and weight, whether high or low achievers.

2.3 There is no significant difference between the high- and low-achieving sample subgroups in terms of the number of problem-nonrelated conceptual elements elucidated by the students.

Not Rejected: For the number of problem-nonrelated conceptual elements there was no significant difference between the Worthington high- and low-achieving student subgroups and between the Taiwan high- and low-achieving subgroups. Students in a common cultural pattern responded similarly to stimulus words, mass and weight, whether high or low achievers.

2.4 There is no significant difference between the high- and low-achieving sample subgroups in terms of the number of physical science conceptual elements elucidated by the students.

Not Rejected: For the number of physical science conceptual elements there was no significant difference between the Worthington high- and low-achieving student subgroups and between the Taiwan high- and low-achieving subgroups. Students in a common cultural pattern behaved similarly in their association of physical science terms with the stimulus words.

2.5 There is no significant difference between the high- and low-achieving sample subgroups in terms of the number of everyday conceptual elements elucidated by the students.

Not Rejected: For the number of everyday conceptual elements there was no significant difference between the high- and low-achieving subgroups of either the Worthington or Taiwan student group. Students in a common cultural pattern behaved similarly in their everyday word association.

2.6 There is no significant difference between the high- and low-achieving sample subgroups in terms of the number of additional conceptual elements elucidated by the students.

Not Rejected: For the number of additional conceptual elements there was no significant difference between the high- and low-achieving subgroup of either the Worthington or Taiwan student group. Students in a common cultural pattern behaved similarly in their addition of associated words.

2.7 There is no significant difference between the high- and low-achieving sample subgroups in terms of the number of deleted conceptual elements elucidated by the students.

Not Rejected: For the number of deleted conceptual elements there was no significant difference between the high- and low-achieving subgroups of either the Worthington or Taiwan student group. Students in a common cultural pattern behaved similarly in their deletion of associated words.

2.8 There is no significant difference between the high- and low-achieving sample subgroups in terms of the scale of importance of problem-related conceptual elements elucidated by the students.

Not Rejected: For the importance of problem-related conceptual elements there was no significant difference between the high- and low-achieving subgroups of either the Worthington or Taiwan student group. Students in a common cultural pattern perceived similarly the importance of problem-related conceptual elements.

2.9 There is no significant difference between the high- and low-achieving sample subgroups in terms of the scale of importance of problem-nonrelated conceptual elements elucidated by the students.

Not Rejected: For the importance of problem-nonrelated conceptual elements there was no significant difference between the high- and low- achieving subgroups of either the Worthington or Taiwan student group. Students in a common cultural pattern perceived similarly the importance of problem-nonrelated conceptual elements.

2.10 There is no significant difference between the sample subgroups of high and low achievements in terms of the number of overlapping conceptual elements elucidated by the students.

Not Rejected: For the number of overlapping conceptual elements there was no significant difference between the high- and low-achieving subgroups of either the Worthington or Taiwan student group. Students in a common cultural pattern behaved similarly in their overlapping word association.

2.11 There is no significant difference between the sample subgroups of high and low achievements in terms of the number of exclusive conceptual elements elucidated by the students.

Not Rejected: For the number of exclusive conceptual elements there was no significant difference between the high- and low-achieving subgroups of either the Worthington or Taiwan student group. Students in a common culture gave a similar number of exclusive conceptual elements.

2.12 There is no significant difference between the sample subgroups of high and low achievements in terms of the number of correct uses of conceptual elements in the solution of problems.

Not Rejected: For the number of correct uses of conceptual elements in the solution of the problem set there was no significant difference between the high- and low-achieving subgroups of either the Worthington or Taiwan student group. Students in a common cultural pattern behaved similarly in their assignment of associated words to correctly answered test items.

2.13 There is no significant difference between the sample subgroups of high and low achievements in terms of the number of incorrect uses of conceptual elements in the solution of problems.

Not Rejected: For the number of incorrect uses of conceptual elements there was no significant difference between the high- and low-achieving subgroups of either the Worthington or Taiwan student group. Students in a common cultural pattern behaved similarly in their assignment of associated words to incorrect answers.

Hypotheses Concerning Correlation Between Conceptual Elements and Student Achievement

Three hypotheses were established concerning correlations between the student's achievement and his uses of conceptual elements in the solution of problems. The test results are summarized in Table 29 with the hypotheses and statements for rejection or non-rejection presented as follows:

3.1 There is no significant correlation between the student's achievement score and his number of correct uses of conceptual elements in the solution of the problem set.

Rejected: There was a significant correlation between the student's achievement and the number of his correct uses of conceptual elements. The student's number of correct uses of conceptual elements reflected his score on the problem set.

3.2 There is no significant correlation between the student's achievement score and his number of incorrect uses of conceptual elements in the solution of the problem set.

Not Rejected: There was no significant correlation between the

TABLE 29

SUMMARY TABLE FOR HYPOTHETICAL TESTS OF CORRELATIONS BETWEEN STUDENT ACHIEVEMENT AND NUMBER OF USES OF CONCEPTUAL ELEMENTS

Hypothesis	Correlation	Critical Value with an Alpha of .05
3.1	0.559	.455
3.2	-0.414	(df = 17)
3.3	0.833	

achievement of the student and the number of incorrect uses of conceptual elements. The student's behaviors were more confusing in his assignment of associated words to incorrectly answered test items than to correctly answered test items.

3.3 The difference in numbers of correct and incorrect uses of conceptual elements in the solution of the problem set does not correlate significantly to the student's achievement scores.

Rejected: There was a significant correlation between the student's achievement and the difference of his correct and incorrect uses of conceptual elements. The student's achievement score on the problem set was related to the difference of his correct and incorrect uses of conceptual elements in solving problems.

However, the correlation values 0.559 and 0.833 were determined by pooling together the Worthington and Taiwan student groups. Referring to the test results of hypotheses 1.12 and 1.13, there was no significant difference between the Worthington and Taiwan student groups with respect to the number of correct uses of conceptual elements, but a significant difference with respect to number of incorrect uses of conceptual elements. The determined correlation 0.559 appeared to reflect a more real correlation between the grade and conceptual element uses than did the determined value 0.833 because of lacking influences of geographical factor. In this connection, the number of correct uses of conceptual elements was further used in cluster analysis.

Summary

The high- and low-achieving subgroups of the Worthington, or the Taiwan, student group did not differ significantly with respect to their association behaviors. However, significant differences between the Worthington and Taiwan student groups turned out to be more meaningful. Cultural differences appeared to have effects on the students' conceptualization of mass and weight.

However, the correlation coefficient between the students' grades and the number of correct uses of conceptual elements was found to be significant. In a sense, the number of correct uses of conceptual elements might be an indicator of the students' grades on the test problems, considering the students' given associations as their self-evaluation tests and the number of correct uses as their grades on these self-evaluation tests. With such a significant correlation, the hypothetical test of factor analysis of the study became an example of cluster analysis usually found in factor analysis textbooks.

A summary of test results is shown in Table 30.

Cluster Analysis of Conceptual Elements

This section contains a discussion of B-coefficient, a restatement of hypotheses for cluster analysis, results obtained, and a summary of cluster groups and separate conceptual elements.

B-coefficient

The B-coefficient is also called Tyron's coefficient of belonging. It is defined as 200 times the ratio of the average intercorrelations among the variables of a group to their average correlations with all the remaining variables. In other words, when the average correlations of variables in the group are higher than their average correlations with all the remaining variables, there appears to

TABLE 30

SUMMARY TABLE FOR ANALYSIS OF VARIANCE RESULTS

Hypothesis Classification	Cross-Cultural Comparison Results	High- and Low-Achieving Subgroup Comparison Results
Overall Number	Not Rejected	Not Rejected
Problem-related Number	Rejected	Not Rejected
Problem-nonrelated Number	Not Rejected	Not Rejected
Physical Science Number	Rejected	Not Rejected
Everyday Number	Not Rejected	Not Rejected
Additional Number	Rejected	Not Rejected
Deletion Number	Not Rejected	Not Rejected
Importance of Problem-related Elements	Not Rejected	Not Rejected
Importance of Problem-non-related Elements	Not Rejected	Not Rejected
Overlapping Number	Not Rejected	Not Rejected
Exclusive Number	Rejected	Not Rejected
Number of Correct Uses	Not Rejected	Not Rejected
Number of Incorrect Uses	Rejected	Not Rejected
Correlation Between Grade and Correct Uses of Conceptual Elements	Rejected*	
Correlation Between Grade and Incorrect Uses of Conceptual Elements	Not Rejected*	
Correlation Between Grade and Difference of Correct and Incorrect Uses of Conceptual Elements	Rejected*	

*The student groups were pooled in the test.

be a cluster group of variables.

The decision to retain or reject a new variable is a judgmental one because there is no test of statistical significance for the B-coefficient. Harman (1967) used a 52 point drop in B-coefficient to reject a new item from a group of three items. In this study, a B-coefficient drop of ten points was assumed to be a significant drop for the Worthington and Taiwan student groups, and a drop of forty points was assumed to be significant for the high- and low-achieving subgroups of the Worthington and Taiwan groups.

Cluster Analysis for Worthington High-achieving Student Subgroup

4.1 There is no conceptual element cluster for the subgroup of Worthington high-achieving students (Tables 31 and 32).

The Worthington high-achieving student subgroup used 41 of the conceptual elements perceived in mass to solve the problem set. Three of the conceptual elements were found to belong to one cluster group, and 38 seemed to be nonrelated.

For the concept of weight there were 31 conceptual elements used by Worthington high achievers to solve the problem set. Seven elements seemed to be nonrelated.

4.2 There is no conceptual element cluster for the subgroup of Worthington low-achieving students (Table 33).

The Worthington low-achieving student subgroup used 36 of the conceptual elements perceived in mass to solve the problem set. Six of the conceptual elements were found to belong to two cluster groups, and

TABLE 31

CLUSTER ANALYSIS OF CONCEPTUAL ELEMENTS PERCEIVED IN MASS BY WORTHINGTON HIGH-ACHIEVING SUBGROUP

Element Combination	B-coefficient	Cluster Elements
PMW (22,33)	1284.5	velocity, f = m x a,
PMW (22,33,44)	1296.8	formula

TABLE 32

CLUSTER ANALYSIS OF CONCEPTUAL ELEMENTS PERCEIVED IN WEIGHT BY WORTHINGTON HIGH-ACHIEVING SUBGROUP

Element Combination	B-coefficient	Cluster Elements
PWW (7,13)	423.1	heavy, gram,
PWW (7,13,19)	397.1	volume
PWW (11,13)	339.5	altitude, gram,
PWW (11,13,15)	366.7	newton
PWW (13,21)	133.6	gram, earth,
PWW (13,21,29)	135.4	unit

TABLE 33

CLUSTER ANALYSIS OF CONCEPTUAL ELEMENTS PERCEIVED IN MASS BY WORTHINGTON LOW-ACHIEVING SUBGROUP

Element Combination	B-coefficient	Cluster Elements
PMW (10,17)	564.6	scale, science,
PMW (10,17,24)	582.6	earth
PMW (3,23)	308.7	density, altitude,
PMW (3,23,43)	279.2	$F = G \frac{MM'}{R^2}$

thirty conceptual elements seemed to be nonrelated.

For the concept of weight there were twenty-seven conceptual elements used by the Worthington low-achieving subgroup. All of the conceptual elements seemed to be used unrelatedly, and no cluster was found in the analysis.

4.3 There is no conceptual element cluster for the subgroup of Taiwan high-achieving students (Tables 34 and 35).

The Taiwan high-achieving student subgroup used thirty-nine of the conceptual elements perceived in mass to solve the problem set. Fourteen of the conceptual elements were found to belong to nine cluster groups, and twenty-five conceptual elements seemed to be nonrelated.

For the concept of weight there were forty-one conceptual elements used in the solution of the problem set. Eleven elements were found to belong to five cluster groups, and thirty conceptual elements seemed to be nonrelated.

4.4 There is no conceptual element cluster for the subgroup of Taiwan low-achieving students (Tables 36 and 37).

The Taiwan low-achieving student subgroup used fifty-four conceptual elements involved in mass to solve the problem set. Thirty-five of the elements were found to belong to eighteen cluster groups, and nineteen conceptual elements seemed to be nonrelated.

For the concept of weight there were forty-one conceptual elements used in the solution of the problem set. Thirteen elements were found to belong to five cluster groups, and twenty-eight conceptual elements seemed to be nonrelated.

TABLE 34

CLUSTER ANALYSIS OF CONCEPTUAL ELEMENTS PERCEIVED IN MASS BY TAIWAN HIGH-ACHIEVING SUBGROUP

Element Combination	B-coefficient	Cluster Elements
PMT (1,12)	594.9	weight, gram,
PMT (1,12,23)	612.9	calculation
PMT (10,12)	567.5	measurement, gram,
PMT (10,12,14)	565.7	matter
PMT (13,18)	505.0	center of mass, unit,
PMT (13,18,23)	468.5	calculation,
PMT (13,18,23,28)	514.8	newton
PMT (6,10)	490.4	constant, measurement,
PMT (6,10,14)	465.4	matter,
PMT (6,10,14,18)	439.5	unit
PMT (3,13)	477.3	conservation of mass, center of mass,
PMT (3,13,23)	482.2	calculation
PMT (1,2)	453.8	weight, gravity,
PMT (1,2,3)	444.9	conservation of mass
PMT (2,3)	357.2	gravity, conservation of mass,
PMT (2,3,4)	309.2	balance,
PMT (2,3,4,5)	398.3	substance,
PMT (2,3,4,5,6)	400.0	constant
PMT (6,14)	292.5	constant, matter,
PMT (6,14,22)	261.8	velocity
PMT (12,13)	269.3	gram, center of mass,
PMT (12,13,14)	304.5	matter

TABLE 35

CLUSTER ANALYSIS OF CONCEPTUAL ELEMENTS PERCEIVED IN WEIGHT BY TAIWAN HIGH-ACHIEVING SUBGROUP

Element Combination	B-coefficient	Cluster Elements
PWT (23,30) PWT (23,30,37)	609.1 579.0	light, spring, velocity
PWT (1,4) PWT (1,4,7)	602.9 593.5	gravity, body weight, unit
PWT (7,8) PWT (7,8,9)	581.9 584.8	unit, earth, mg
PWT (8,9) PWT (8,9,10)	543.8 515.9	earth, mg, substance
PWT (17,27) PWT (17,27,37)	475.0 485.8	volume, metal, velocity

TABLE 36

CLUSTER ANALYSIS OF CONCEPTUAL ELEMENTS PERCEIVED IN MASS BY TAIWAN LOW-ACHIEVING SUBGROUP

Element Combination	B-coefficient	Cluster Elements
PMT (12,38)	726.3	gram, particle,
PMT (12,38,64)	723.4	metal
PMT (7,23)	455.8	acceleration, calculation,
PMT (7,23,39)	463.7	body weight
PMT (51,55)	432.7	relativity, light,
PMT (51,55,59)	456.8	displacement
PMT (40,41)	432.7	equipment, size,
PMT (40,41,42)	456.8	concept
PMT (41,50)	432.7	size, existence,
PMT (41,50,59)	456.8	displacement
PMT (40,50)	432.7	equipment, existence,
PMT (40,50,60)	456.8	loss
PMT (21,40)	432.2	force, equipment,
PMT (21,40,59)	456.5	displacement
PMT (18,37)	418.8	unit, heavy,
PMT (18,37,56)	446.3	weightlessness
PMT (2,30)	386.7	gravity, proton,
PMT (2,30,58)	417.8	spring balance
PMT (27,41)	383.7	motion, size,
PMT (27,41,55)	420.3	apple
PMT (20,29)	363.8	momentun, $E = mc^2$,
PMT (20,29,38)	388.5	particle
PMT (5,11)	276.1	substance, scale,
PMT (5,11,17)	292.1	physics
PMT (5,7)	274.6	substance, acceleration,
PMT (5,7,9)	253.1	density,
PMT (5,7,9.11)	271.8	scale

(Continued on next page)

Table 36. (Continued)

Element Combination	B-coefficient	Cluster Elements
PMT (4,27)	255.5	balance, motion,
PMT (4,27,50)	251.1	existence
PMT (22,28)	195.0	velocity, newton,
PMT (22,28,34)	160.6	vector
PMT (17,19)	154.5	physics, kinetic energy,
PMT (17,19,21)	135.3	force
PMT (19,23)	134.2	kinetic energy, calculation,
PMT (19,23,27)	161.6	motion
PMT (28,33)	122.8	newton, molecule,
PMT (28,33,38)	160.6	particle

TABLE 37

CLUSTER ANALYSIS OF CONCEPTUAL ELEMENTS PERCEIVED IN WEIGHT BY TAIWAN LOW-ACHIEVING SUBGROUP

Element Combination	B-coefficient	Cluster Element
PWT (7,24)	240.4	unit, newton,
PWT (7,24,41)	255.7	work
PWT (7,18)	240.4	unit, physics,
PWT (7,18,29)	250.2	density
PWT (17,22)	186.6	volume, weightlessness,
PWT (17,22,27)	197.6	metal
PWT (7,31)	162.0	unit, attraction,
PWT (7,31,55)	179.8	rest situation
PWT (3,4)	117.0	mass, body weight,
PWT (3,4,5)	108.5	non-constant

4.5 There is no conceptual element cluster for the group of Worthington students as a whole (Tables 38 and 39).

The Worthington student group used fifty-six of the conceptual elements involved in mass to solve the problem set. Fourteen of the conceptual elements were found to belong to six cluster groups, and forty-two conceptual elements seemed to be nonrelated.

For the concept of weight there were forty-three conceptual elements used in the solution of the problem set. Three of the conceptual elements were found to belong to one cluster group and forty conceptual elements seemed to be nonrelated.

4.6 There is no conceptual element cluster for the group of Taiwan students as a whole (Table 40).

The Taiwan student group used sixty-six of the conceptual elements involved in mass to solve the problem set. Twenty of the elements were found to belong to nine cluster groups, and forty-six conceptual elements seemed to be nonrelated.

For the concept of weight the Taiwan student group used fifty-seven of the conceptual elements in the solution of the problem set. No cluster group was found in the study.

Cluster Hierarchy

Further analysis of clusters indicated that some cluster groups had common conceptual elements with other clusters. In other words, some clusters were built on other clusters and might be at a higher hierarchical level than others in the students' cognitive structure.

TABLE 38

CLUSTER ANALYSIS OF CONCEPTUAL ELEMENTS PERCEIVED IN MASS BY WORTHINGTON STUDENT GROUP

Element Combination	B-coefficient	Cluster Elements
PMW (7,17)	1093.8	matter, science,
PMW (7,17,27)	1087.1	solid
PMW (4,22)	374.9	force, velocity,
PMW (4,22,40)	384.7	field
PMW (1,17)	154.3	weight, science,
PMW (1,17,33)	148.1	f = m x a
PMW (40,43)	148.7	field, $F = G \frac{MM'}{R2}$,
PMW (40,43,46)	143.2	direction
PMW (24,30)	144.4	earth, physics,
PMW (24,30,36)	144.2	molecule
PMW (1,5)	115.9	weight, gram,
PMW (1,5,9)	121.1	measurement

TABLE 39

CLUSTER ANALYSIS OF CONCEPTUAL ELEMENTS PERCEIVED IN WEIGHT BY WORTHINGTON STUDENT GROUP

Element Combination	B-coefficient	Cluster Elements
PWW (7,14)	735.4	heavy, light,
PWW (7,14,21)	735.7	earth

TABLE 40

CLUSTER ANALYSIS OF CONCEPTUAL ELEMENTS PERCEIVED IN MASS BY TAIWAN STUDENT GROUP

Element Comb ation	B-coefficients	Cluster Elements
PMT (11,37)	431.3	scale, heavy,
PMT (11,37,63)	430.6	lifting
PMT (18,23)	390.1	unit, calculation,
PMT (18,23,28)	393.9	newton
PMT (1,12)	333.9	weight, gram,
PMT (1,12,23)	325.9	calculation
PMT (1,2)	302.9	weight, gravity,
PMT (1,2,3)	292.0	conservation of mass
PMT (7,27)	194.4	acceleration, motion,
PMT (7,27,47)	193.1	spring
PMT (1,31)	192.1	weight, potential energy,
PMT (1,31,61)	183.6	attraction
PMT (11,18)	172.8	scale, unit,
PMT (11,18,25)	167.4	conservation of energy,
PMT (15,18)	169.8	F = m x a, unit,
PMT (15,18,21)	162.7	force
PMT (10,27)	135.3	measurement, motion,
PMT (10,27,44)	135.6	space

Since the cluster with a larger B-coefficient had larger correlatedness among its conceptual elements than the cluster with a smaller B-coefficient, a cluster with a high B-coefficient was considered firmly embedded in the students' cognitive domain and might be formed according to the student's learned experience. On the other hand, the cluster with a low B-coefficient had conceptual elements with a low correlation to one another. This could be an indication of the student's opinion, especially about the problem set used in the study. Hence, the clusters with lower B-coefficients were analyzed in terms of conceptual elements involved in the clusters with higher coefficients to build a hierarchical structure.

The procedures used in the study involved the arrangement of cluster groups in an order of decreasing B-coefficients and the assortment of conceptual elements of a lower B-coefficient to elements of a higher B-coefficient. This method was applicable to seven of the ten lists of clusters. The results are shown in Tables 41, 42, 43, 44, 45, 46, and 47 with the clusters at higher levels named by the remaining conceptual element or elements. Cluster groups within a level are not hierarchical.

Summary

The students' numbers of correct uses of conceptual elements perceived in mass and weight were used to determine the correlation matrices. The matrices served in turn to calculate the B-coefficient of conceptual element clusters.

TABLE 41

HIERARCHICAL STRUCTURE OF CLUSTER GROUPS WITH CONCEPTUAL ELEMENTS PERCEIVED IN MASS BY WORTHINGTON HIGH-ACHIEVING SUBGROUP

Level 2	earth, unit	altitude, newton
Level 1	heavy, gram, mass	

TABLE 42

HIERARCHICAL STRUCTURE OF CLUSTER GROUPS WITH CONCEPTUAL ELEMENTS PERCEIVED IN MASS BY TAIWAN HIGH-ACHIEVING SUBGROUP

Level 4	substance, balance	constant	
Level 3	gravity	conservation of mass	velocity
Level 2	center of mass, unit, newton	measurement, matter	
Level 1	weight, gram, calculation		

Note: One cluster group consisting of gram, center of mass, and matter disappears because it was entirely built on elements of other clusters.

TABLE 43

HIERARCHICAL STRUCTURE OF CLUSTER GROUPS WITH CONCEPTUAL ELEMENTS PERCEIVED IN WEIGHT BY TAIWAN HIGH-ACHIEVING SUBGROUP

Level 3	substance	
Level 2	earth, mg	metal, volume
Level 1	gravity, body weight, unit	light, spring, velocity

TABLE 44

HIERARCHICAL STRUCTURE OF CLUSTER GROUPS WITH CONCEPTUAL ELEMENTS PERCEIVED IN MASS BY TAIWAN LOW-ACHIEVING SUBGROUP

Level 4		density	
Level 3	kinetic energy	force	molecule
	balance	existance	loss
Level 2		momentum, $E = mc^2$	motion, apple
Level 1	gram, particle, metal	relativity, light, displacement	equipment, size, concept
	unit, heavy, weightlessness	gravity, proton, spring balance	acceleration, calculation, body weight
	substance, scale, physics	velocity newton, vector	

Note: One cluster group consisting of kinetic energy, calculation, and motion disappears because it was entirely built on elements of other clusters.

TABLE 45

HIERARCHICAL STRUCTURE OF CLUSTER GROUPS WITH CONCEPTUAL ELEMENTS PERCEIVED IN WEIGHT BY TAIWAN LOW-ACHIEVING SUBGROUP

Level 2	attraction, rest situation		physics, density
Level 1	unit, newton, work	mass, body weight, nonconstant	volume, weightlessness, metal

TABLE 46

HIERARCHICAL STRUCTURE OF CLUSTER GROUPS WITH CONCEPTUAL ELEMENTS PERCEIVED IN MASS BY WORTHINGTON STUDENT GROUP

Level 3		weight	
Level 2	$F = G\frac{MM'}{R^2}$, direction		gram, measurement
Level 1	matter, science, solid	force, velocity, field	earth, physics, molecule

TABLE 47

HIERARCHICAL STRUCTURE OF CLUSTER GROUPS WITH CONCEPTUAL ELEMENTS PERCEIVED IN MASS BY TAIWAN STUDENT GROUP

Level 3		conservation of energy	
Level 2	measurement, space	gravity, conservation of mass	F = ma, force
	potential energy, attraction	weight, gram	
Level 1	scale, heavy, lifting	acceleration, motion, spring	unit, calculation, newton

Cluster analysis allowed the investigator to understand the students' idea about the problem set used in the study. For example, comparison of Tables 42 and 43 shows that the Taiwan high-achieving student subgroup perceived both mass and weight from the viewpoint of "substance," and thus most terms involved in the hierarchical cluster structure were descriptive of "substance."

Using Tables 46 and 47, it can be seen that the Worthington student group perceived mass on the basis of weight and the Taiwan student group, on the basis of conservation of energy. Although both groups had some similarities in conceptual elements used in solving the problem set, such as measurement, gram, and force, emphasis upon conservation of mass and potential energy were found for the Taiwan group in contrast with emphasis upon field, direction, and earth for the Worthington group.

The study was focused on cross-cultural comparison between two student groups. It was intended to find some exemplar cluster groups for a specific student group. In this connection, the calculation of B-coefficients by means of a program, using Fortran IV language, developed for this study appeared to be appropriate. The program used in this study is limited to searching for cluster groups with the conceptual elements skipped over at a definite interval. For a more thorough study of cluster groups and their hierarchical structures concerning some kind of instructional material, a revision of the B-coefficient program is needed.

CHAPTER V

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

Statement of Problem

The focus of this study was to assess the effects of cultural differences on the perception of conceptual elements involved in two physics concepts. Senior high school student groups from Worthington and Taiwan were used, consisting of nineteen matched pairs (one Worthington and one Taiwan student). The students were matched on four variables: sex, IQ, reading ability, and average science grade. The two concepts, mass and weight, are similarly taught in PSSC courses offered in Worthington and Taiwan. The students enrolled in these courses should attain comparable outcomes which include cognitive understanding and problem solving skills, unless affected by cultural backgrounds.

Cultural effects were assessed by analyzing the numbers of different types of conceptual elements elucidated by Worthington and Taiwan student groups. The conceptual elements were classified into eight categories: problem-related, problem-nonrelated, physical science, everyday, additional, deleted, overlapping, and exclusive conceptual elements. In addition, the students' rating of the importance of the problem-related and problem-nonrelated conceptual elements was determined by means of an importance scale. The number of times a problem-related conceptual element was used both correctly and incorrectly by the students in solving the problem set devised for the study was another variable investigated.

Further analysis was conducted by determining correlations between student achievement and number of uses of conceptual elements in solving the problem set. Significant correlations served as the basis for cluster analysis of conceptual elements in terms of their correct uses. Sequencing order of importance of conceptual elements served as a prerequisite correlational condition for clustering.

Results from cluster analysis were explained by means of hierarchical structures in order to examine the underlying idea that the students of a specific group possessed concerning the problem set.

Conclusions

The two cultural groups were found to behave similarly in most of their association behaviors. This is reflected in the graphs illustrating frequency distributions of conceptual elements perceived in mass and weight by the students (Chapter IV, Figures 3-9). The observed differences in the students' elucidation of conceptual elements are explainable in terms of cultural diversity, such as differences in the semantic meaning implied in mass in English and in Chinese, social attitudes toward the scientific enterprise, traditional approach to learning, economic level, and pressures of the entrance examination. The matching techniques served satisfactorily in the selection of two matched student groups from two different cultures for the study.

Conceptual Elements Perceived in Mass

The total number of conceptual elements perceived in mass was 101 for the Worthington student group and ninety-six for the Taiwan student group, which was not a significant difference. This suggests that the scope of mental repertory and the rate at which a student associated words with the stimulus "mass" were comparable for Worthington and Taiwan student groups. Test results of hypothesis 1.1 support this conclusion.

As stated in Chapter III, mass has as varied a meaning as the service of the Eucharist in English and as "quality" in Chinese. For the Worthington student group, more than one third of the forty-five problem-nonrelated conceptual elements perceived in mass were found to be related to religion. For the Taiwan student group, only one out of thirty problem-nonrelated conceptual elements perceived in mass was related to "quality." Since both the Worthington and Taiwan groups of students were exposed to the same example given in the word association pretest which was deliberately designed to elicit crude experimental associations, the difference in the number of semantically identical terms suggests that the students in Taiwan were less divergent in their thinking than were the students in Worthington.

Conceptual Elements Perceived in Weight

The total number of conceptual elements perceived in weight was eighty-nine for the Worthington student group and ninety for the Taiwan student group. Efficiency of associating words with a stimulus was comparable for Worthington and Taiwan student groups.

For the problem-nonrelated part of the conceptual elements perceived in weight, about one-sixth of the forty-six terms were related to body image for the Worthington student group. By comparison, about one-eighth of the thirty-three problem-nonrelated terms perceived in weight related to body image for the Taiwan student group. The two cultures represented by the students involved in this study appeared to differ in their concern for health and body image, as shown by the differences in elicited life science terms. This difference may be influenced by differences in economic achievement.

Conceptual Elements Versus Cultural Backgrounds

The Worthington and Taiwan groups were not significantly different in terms of the number of elicited overlapping conceptual elements in response to the stimulus words, mass and weight. Generally speaking, overlapping conceptual elements reflect the confusion in distinguishing between the concepts of mass and weight. Hence, understanding of mass and weight concepts was basically similar for both Worthington and Taiwan student groups.

However, for problem-related and additional conceptual elements, there were significnat differences between Worthington and Taiwan student groups. Taiwan students were apparently influenced by the test form (the problem set) which was at hand when fulfilling the additional task in the word association post-test because the problem set was the source of most of their additional elements. The problem set was representative of the authority of the examiner. The Taiwan student group appeared more dominated by the authority of the examiner than did the Worthington student group.

This conclusion is also evident through an examination of the significant results for hypothesis 1.4. The terms appearing in the test form were by nature problem-related and generally in the physical science category. Taiwan students used terms from the test form as their additional conceptual elements. Hence, the rejection of the hypotheses that there are no significant differences between the numbers of additional conceptual elements and between the numbers of problem-related conceptual elements was accompanied by the rejection of the hypothesis that there is no significant difference between the numbers of physical science conceptual elements for the two student groups.

Moreover, the inclination of Taiwan students to take terms from the problem set as their additional conceptual elements can be explained as a behavior to attain a higher score on the word association tests. The Taiwan student group was more concerned with the score obtained on the tests than was the Worthington student group. Since the Taiwan students were under pressures of the annual entrance examination when taking the tests used in the study, their behavior of adding terms appearing in the problem set to their conceptual elements is explainable.

Analysis of conceptual elements perceived in mass and weight showed that the Taiwan student group associated more physics terms at a higher level of understanding with the stimulus words, mass and weight, than did the Worthington student group. Some of the terms included were relativity, $E = mc^2$, and Millikan oil drop experiment.

If these terms are not entirely understood by a student, then their appearance in his word association list might suggest a greater amount of memorization. Memorization is favored by traditional Chinese scholars. Many teachers stress this aspect of learning even in physics in Taiwan. Such influences seem to be a reason for the significant difference in the number of physical science conceptual elements for Worthington and Taiwan student groups.

In summary, it is concluded that the understanding of the mass and weight concepts was similar for both Worthington and Taiwan student groups. Both groups paid similar attention to physical science terms. The students in Taiwan behaved differently in some aspects than did those in Worthington because of their special attitudes toward the authority of tests, test examiners, learning by memory, and the entrance examination.

Conceptual Elements Versus Student Achievement

Two-way analysis of variance of the data showed the absence of interactions between the categories of high- and low-achievement and the types of culture (Worthington and Taiwan). It is concluded that there was no relationship between the students' elucidation of conceptual elements and their achievement on the physics problem set. This might result either from the low reliability of the problem set used in the study to dichotomize the student groups or from a real absence of differences in conceptual elements perceived by the high- and low-achieving student subgroups with a common cultural pattern. If the latter possibility is true, then the cultural effects on perceptions of physical science conceptual elements are more marked than are the effects of student achievement on the problem set.

Conceptual Element Clusters and Cultural Background

Conceptual element clusters were analyzed by means of a hierarchical presentation to assess the conceptual elements used by a specific group of students to solve the problem set. Many conceptual elements were found to be equally used by both Worthington and Taiwan student groups. These included such conceptual elements as measurement, gram, $f = m \times a$, $F = G \frac{MM'}{R^2}$, volume, unit, physics, newton, and scale. Most of the everyday conceptual elements perceived in mass and weight by the students disappeared in these hierarchical structures. In terms of use of conceptual elements in the solution of the problem set, Worthington and Taiwan student groups were comparable to each other. In other words, physics can be described as an international science field, especially in the problem solving skills involved.

However, the number of conceptual element clusters differed for Worthington and Taiwan student groups. The total number was seven for the Worthington group and nine for the Taiwan group. The differences might be greater if a more thorough search for cluster groups were performed. Since cluster groups reflect the students' uses of conceptual elements to solve the problem set by following some kind of available patterns (e.g., text materials), this difference may be a result of the students' application of varying memorized experience to the problem set for Worthington and Taiwan groups.

Conceptual Element Clusters and Achievement

There were no cluster groups common to Worthington and Taiwan subgroups (high and low academic achievement). The methods each subgroup used to solve the problem set differed greatly. Individual differences appear to be an important factor in the learning of physics.

However, from Tables 42-45 (Chapter IV), it can be seen that the conceptual elements "substance" and "density" were common to the Taiwan high-achieving and low-achieving subgroups. It is concluded that the Taiwan high-achieving and low-achieving student subgroups held some common understanding of the problem set.

Recommendations

Physics Instruction

Based on the conclusions reported, the following recommendations are made. Due to the investigator's background, these appear especially suitable for Taiwan although they may have equal applicability for the teaching of physics in the United States secondary schools.

1. The evidence showed that the conceptual elements perceived in mass and weight by the students of a specific culture were affected by their cultural background. Selection of instructional materials from local resources for physics teaching can enhance the cultural effects and make it possible for the students to obtain more learning outcomes and find more societal relevancy in physics learning. The teaching of a translated physics course to the entire student population at the senior high school level is far from a perfect method of improving science education.

2. Physics is an international science field with physics subject

matter taught to students of different cultural backgrounds. However, translations of foreign scientific articles, particularly related to up-to-date information, should be used as supplementary instructional materials to help brighter students or students interested in the field in acquiring in-depth knowledge, and not as the materials of a required course for the entire student population.

3. Students from a more conservative society were found to be less divergent in their responses to the stimulus words: mass and weight. More emphasis should be placed on motivating students to actively participate in physics learning and problem solving. Instruction through discussion, student projects, inquiry techniques, and through learning by discovery is a necessary measure to compensate for this weakness.

Further studies

Recommendations for further studies are as follows:

1. The national entrance examination appears to be a pressure on the Taiwan students but also an impetus for intensive learning of physics subject matter. Further study is recommended of the effects of the entrance examination on physics learning to find an effective way of administering entrance examinations without forming an atmosphere encouraging the examinees to learn the physics content by memory. This may involve construction of test batteries, changes in societal attitudes toward entrance examinations, and changes in teachers' attitudes toward teaching of college-preparatory courses.

2. Memorization is effective in enlarging a student's repertory of physics terms. However, memorization is also the origin of a student's

dependence on available examples in the solution of problems. Further study is recommended on the investigation of methods for strengthening the effect of memorization on physics learning and simultaneously enhancing the student's independence in problem solving.

3. Elucidation of conceptual elements involved in physics concepts and hierarchical presentation of the cluster conceptual elements through B-coefficient calculation were found to be effective ways to identify the strategy a student used in problem solving. Further study is recommended of the hierarchical structure involved in solution of the problem set to determine the different element clusters used by students in solving physics problems.

4. Cultural effects on the students' perceptions of conceptual elements in physics terms were found in this study. It is suggested that a study be made concerning socio-economic effects on students' perceptions of physical science conceptual elements.

APPENDIX A

NORMATIVE DATA ON CTMM CHINESE VERSION FOR MALES

NORMATIVE DATA ON CTMM CHINESE VERSION FOR FEMALES

NORMATIVE DATA ON CTMM CHINESE VERSION FOR MALES

Age	Grade	N	Statistics	Opposites	Similarities	Analogies	F_1	Number Problems	Number Series	F_2	Verbal Comprehension	Delayed Recall	Language	Nonlanguage	Total
				Subtests, Factors (F), Parts and Total Score											
15	9	482	M	5.32	7.68	7.28	20.66	13.78	7.06	20.96	18.58	16.76	49.12	28.72	77.84
			S.D.	2.37	2.26	2.24	4.44	2.63	2.84	3.99	3.18	3.48	8.60	6.40	13.25
16	10	296	M	5.23	7.89	7.03	20.06	13.17	6.47	19.69	18.54	16.25	47.96	26.53	74.49
			S.D.	2.50	2.51	2.26	5.48	3.07	2.26	4.30	3.19	3.81	8.62	6.00	13.05
17	11	260	M	5.76	8.54	8.23	21.88	13.29	7.17	21.01	19.20	17.60	50.09	29.05	80.14
			S.D.	2.29	2.50	2.37	4.71	2.67	2.47	4.45	3.42	3.06	8.64	6.20	13.45
18	12	226	M	5.69	8.12	7.57	21.35	13.24	7.19	20.47	19.38	16.46	47.89	27.96	76.85
			S.D.	2.17	2.17	2.13	4.51	3.31	2.11	4.01	3.00	3.36	8.62	6.60	13.25
	Total	1264	M	5.46	7.99	7.28	20.66	13.78	7.06	20.96	18.58	16.76	47.89	27.96	76.85
			S.D.	2.37	2.36	2.25	4.73	3.17	2.51	4.18	3.13	3.38	8.62	6.60	13.25
				0.15	0.22	0.20	0.58	0.39	0.20	0.59	0.52	0.47	0.97	0.38	0.76
				0.047	0.047	0.045	0.094	0.063	0.050	0.083	0.062	0.067	0.49	0.19	0.39

Source: Examiner's Manual of the California Short-form Test of Mental Maturity, Chinese Version, Taipei: The National Taiwan University, 1971, 7.

NORMATIVE DATA ON CTMM CHINESE VERSION FOR FEMALES

Age	Grade	N	Statistics	Opposites	Similarities	Analogies	F_1	Number Problems	Number Series	F_2	Verbal Comprehension	Delayed Recall	Language	Nonlanguage	Total
				Subtests, Factors (F), Parts and Total Scores											
15	9	435	M	5.12	7.35	6.21	18.86	13.53	6.90	20.42	17.96	16.57	48.06	25.76	74.82
			S.D.	2.31	2.19	2.05	3.69	2.52	2.24	3.60	3.05	2.96	12.10	5.59	17.16
16	10	332	M	5.29	7.50	6.03	18.67	11.22	6.38	17.37	18.46	15.96	45.64	25.05	70.70
			S.D.	2.38	2.00	2.07	4.46	3.28	2.09	4.12	3.16	3.32	12.00	5.54	17.08
17	11	353	M	4.93	7.35	5.82	18.08	11.20	6.43	17.45	18.37	14.99	44.56	24.51	69.07
			S.D.	2.62	2.18	2.17	4.48	2.90	2.07	3.95	3.14	3.68	12.02	5.56	17.03
18	12	278	M	5.14	7.23	6.82	18.84	11.53	6.79	18.20	19.74	16.28	47.55	25.63	73.18
			S.D.	2.26	2.55	2.04	4.53	3.12	2.36	4.60	3.14	2.96	12.06	5.62	17.12
	Total	1398	M	5.12	7.28	6.19	18.62	11.10	6.63	18.50	18.54	15.97	46.50	24.98	71.48
			S.D.	2.39	2.02	2.09	4.35	2.87	2.19	3.97	3.14	3.24	12.06	5.69	17.12
				0.14	0.20	0.17	0.51	0.3	0.18	0.51	0.43	0.44	0.69	0.33	0.99
				0.045	0.038	0.039	0.025	0.025	0.041	0.075	0.059	0.06	0.35	0.17	0.50

Source: Examiner's Manual of the California Short-form Test of Mental Maturity, Chinese Version, Taipei: The National Taiwan University, 1971, 7.

APPENDIX B

SPLIT-HALF RELIABILITY COEFFICIENTS

SPLIT-HALF RELIABILITY COEFFICIENTS

Sub-tests	Opposites	Simi-larities	Analogies	Number Problems	Number Series	Verbal Compre-hension	Delayed Recall
r	0.52	0.32	0.66	0.80	0.44	0.54	0.68

Source: Examiner's Manual of the California Short-form Test of Mental Maturity, Chinese Version, Taipei: The National Taiwan University, 1971, 8.

APPENDIX C

WORD ASSOCIATION PRETEST

WORD ASSOCIATION POSTTEST

WORD ASSOCIATION EXERCISE I

FOR

PSSC PHYSICS STUDENTS

Name ______________________________
Sex (Please circle: Male, Female)
Parental Occupation:
Father ___________________________
Mother ___________________________

This exercise consists of two parts. Each part starts with a stimulus word. In thinking about this word, a number of other words may come to mind. The association of words results from our experience in reading books, doing homework, completing laboratory activities, and in leading our daily lives.

Please write down all the words that you associate with the stimulus word. The list should be as complete as possible (but don't worry too much about correct spelling).

The associated word may be either a single word or a phrase, preferably including a predicate.

Be sure that both parts are completed.

For example: Stimulus word ----------Horse

1. Animal
2. Four feet
3. Saddle
4. Reins
5. Rider
6. Jumping
7. Running
8. Racing
9. Betting
10. Speed
11. Horse power
12. Donkey
13. Mule
14. Carriage
15. Cart
16. Polo
17. Whip
18. Spurs
19. Horse sense
20. Horse radish
21. Stable
22. ____________________

The time limit for the first stimulus word is 6 minutes. STOP here until you are instructed to begin.

PART ONE

Stimulus word-------Mass

1.

2.

3.

4.

5.

6.

7.

8.

9.

10.

11.

12.

13.

14.

15.

16.

17.

18.

19.

20.

21.

22.

23.

24.

25.

26.

27.

28.

29.

30.

31.

32.

33.

34.

35.

36.

37.

38.

39.

40.

41.

42.

Having completed this part, STOP here until you are instructed to begin with the second part. The time limit for the second stimulus word is also 6 minutes.

PART TWO

Stimulus word--------Weight

1.

2.

3.

4.

5.

6.

7.

8.

9.

10.

11.

12.

13.

14.

15.

16.

17.

18.

19.

20.

21.

22.

23.

24.

25.

26.

27.

28.

29.

30.

31.

32.

33.

34.

35.

36.

37.

38.

39.

40.

41.

42.

WORD ASSOCIATION EXERCISE II

FOR

PSSC PHYSICS STUDENTS

This exercise consists of two major parts.

Part One begins on page 2 with one set of instructions, and Part Two begins on page 32 with another set of instructions. Be sure that both parts are completed carefully.

Now, turn to page 2.

PART ONE

Instructions:

In this part, you will find the two stimulus words presented in Exercise 1.

All the associated words you wrote down in Exercise 1 are given in the first columm under the heading of the stimulus word.

If you wish to eliminate an original associated word, please cross it out.

For example: Stimulus word---Mass

Your Original Associated Word	Question Number	Yes
1. Humanity	1	( )
	2	( )
	3	( )
	4	( )
	.	.
	.	.

If you keep an original associated word, you are requested to check whether you used it in answering your questions. In so doing, first, read the question number appearing in the second column and recall the content of this question number by referring to it in your accompanying question booklet; then, carefully check whether the associated word was used in solving this question. If "yes," put a check in the blank following the question number; if "no," skip over it and check the same associated word with the next question number. After such an associated word is checked with every question number, work with the next associated word using the same procedures.

For example: Stimulus word---Mass

Your Original Associated Word	Question Number	Yes
1. Humanity	1	(✓)
	2	( )
	3	( )
	4	(✓)
	.	.
	.	.

PART ONE

If you keep an associated word and find that it was not used in answering any question, then leave it as printed and mark nothing in such a space.

For example: Stimulus word---Mass

Your Original Associated Word	Question Number	Yes
1. Humanity	1	( )
	2	( )
	3	( )
	4	( )
	.	.
	.	.

The time limit for this exercise is 45 minutes. Please wait for the examiner's order to start working on page 4.

PART ONE

Stimulus word-----Mass

Your Original Associated Word	Question Number	Yes
1.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
2.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
3.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed your work on "Mass," turn to page 18.

PART ONE

Stimulus Word-----Mass

Your Original Associated Word	Question Number	Yes
4.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
5.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
6.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed your work on "Mass," turn to page 18.

PART ONE

Stimulus word-----Mass

Your Original Associated Word	Question Number	Yes
7.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
8.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
9.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed your work on "Mass," turn to page 18.

PART ONE

Stimulus word-----Mass

Your Original Associated Word	Question Number	Yes
10.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
11.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
12.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed your work on "Mass," turn to page 18.

PART ONE

Stimulus word-----Mass

Your Original Associated Word	Question Number	Yes
13.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
14.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
15.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed your work on "Mass," turn to page 18.

PART ONE

Stimulus word-----Mass

Your Original Associated Word	Question Number	Yes
16.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
17.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
18.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed your work on "Mass," turn to page 18.

PART ONE

Stimulus word-----Mass

Your Original Associated Word	Question Number	Yes
19.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
20.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
21.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed your work on "Mass," turn to page 18.

PART ONE

Stimulus Word-----Mass

Your Original Associated Word	Question Number	Yes
22.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
23.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
24.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed your work on "Mass," turn to page 18.

PART ONE

Stimulus word-----Mass

Your Original Associated Word	Question Number	Yes
25.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
26.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
27.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed your work on "Mass," turn to page 18.

PART ONE

Stimulus word-----Mass

Your Original Associated Word	Question Number	Yes
28.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
29.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
30.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed your work on "Mass," turn to page 18.

PART ONE

Stimulus word-----Mass

Your Original Associated Word	Question Number	Yes
31.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
32.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
33.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed your work on "Mass," turn to page 18.

PART ONE

Stimulus word-----Mass

Your Original Associated Word	Question Number	Yes
34.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
35.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
36.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed your work on "Mass," turn to page 18.

PART ONE

Stimulus word-----Mass

Your Original Associated Word	Question Number	Yes
37.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
38.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
39.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed your work on "Mass," turn to page 18.

PART ONE

Stimulus word-----Mass

Your Original Associated Word	Question Number	Yes
40.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
41.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
42.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed your work on "Mass," turn to page 18.

PART ONE

Stimulus word-----Weight

Your Original Associated Word	Question Number	Yes
1.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
2.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
3.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed this part, turn to page 32.

PART ONE

Stimulus word-----Weight

Your Original Associated Word	Question Number	Yes
4.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
5.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
6.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed this part, turn to page 32.

PART ONE

Stimulus word------Weight

Your Original Associated Word

	Question Number	Yes
7.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
8.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
9.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed this part, turn to page 32.

PART ONE

Stimulus word-----Weight

Your Original Associated Word	Question Number	Yes
10.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
11.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
12.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed this part, turn to page 32.

PART ONE

Stimulus word-----Weight

Your Original Associated Word	Question Number	Yes
13.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
14.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
15.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed this part, turn to page 32.

PART ONE

Stimulus word-----Weight

Your Original Associated Word	Question Number	Yes
16.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
17.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
18.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed this part, turn to pagc 32.

PART ONE

Stimulus word-----Weight

Your Original Associated Word	Question Number	Yes
19.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
20.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
21.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed this part, turn to page 32.

PART ONE

Stimulus word-----Weight

Your Original Associated Word	Question Number	Yes
22.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
23.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
24.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed this part, turn to page 32.

PART ONE

Stimulus word-----Weight

Your Original Associated Word	Question Number	Yes
25.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
26.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
27.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed this part, turn to page 32.

PART ONE

Stimulus word-----Weight

Your Original Associated Word	Question Number	Yes
28.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
29.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
30.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed this part, turn to page 32.

PART ONE

Stimulus word-----Weight

Your Original Associated Word	Question Number	Yes
31.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
32.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
33.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed this part, turn to page 32.

PART ONE

Stimulus word-----Weight

Your Original Associated Word	Question Number	Yes
34.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
35.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
36.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed this part, turn to page 32.

PART ONE

Stimulus word-----Weight

Your Original Associated Word	Question Number	Yes
37.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
38.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
39.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed this part, turn to page 32.

PART ONE

Stimulus word-----Weight

Your Original Associated Word	Question Number	Yes
40.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
41.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
42.	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed this part, turn to page 32.

PART TWO

Instructions:

In the first section of this second part, you will find the stimulus word "Mass." Below this stimulus word, there are a number of underlined spaces, each followed by a complete set of question numbers. A blank space is also placed to the right of each question number.

Because you acquired some new experience in answering your questions and working on Part One, maybe you want to add some new associated words. Write the new associated word in the underlined space. Repeat the same checking procedures as stated in Part One.

For example: Stimulus word---Mass

Your Additional Associated Word	Question Number	Yes
1. Time	1	( )
	2	(✓)
	3	( )
	4	( )
	.	.
	.	.

In the second section of this second part, you will find the stimulus word "Weight." In the space left below this stimulus word, repeat the same adding and checking procedures as before.

Be sure that all new associated words are added in the appropriate space and checked with each of the question numbers.

Turn to page 33, and continue your work.

PART TWO

Section-----1

Stimulus word-----Mass

Your Additional Associated Word	Question Number	Yes
1. ____________________	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
2. ____________________	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
3. ____________________	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed your work with "Mass," turn to page 37.

PART TWO

Stimulus word-----Mass

Your Additional Associated Word	Question Number	Yes
4. ________________	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
5. ________________	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
6. ________________	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed your work with "Mass," turn to page 37.

PART TWO

Stimulus word-----Mass

Your Additional Associated Word	Question Number	Yes
7. ____________	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
8. ____________	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
9. ____________	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed your work with "Mass," turn to page 37.

PART TWO

Stimulus word-----Mass

Your Additional Associated Word	Question Number	Yes
10. ______________________	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
11. ______________________	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
12. ______________________	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

*Having completed your work with "Mass," turn to page 37.

PART TWO

Section------2

Stimulus word-----Weight

Your Additional Associated Word	Question Number	Yes
1. ______________________	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
2. ______________________	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
3. ______________________	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

PART TWO

Stimulus word-----Weight

Your Additional Associated Word	Question Number	Yes
4. ____________	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
5. ____________	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
6. ____________	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

PART TWO

Stimulus word-----Weight

Your Additional Associated Word	Question Number	Yes
7. ____________	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
8. ____________	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
9. ____________	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

PART TWO

Stimulus word-----Weight

Your Additional Associated Word	Question Number	Yes
10. ____________	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
11. ____________	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )
12. ____________	1	( )
	2	( )
	3	( )
	4	( )
	5	( )
	6	( )
	7	( )
	8	( )
	9	( )
	10	( )
	11	( )
	12	( )

APPENDIX D

THE PSSC PROBLEM SET

1. Classificatory Statement:

The mass of a body is described as the measure of inertia.

Test Item

Body A and body B are both 20 kg in mass and are placed at different heights above the surface of the earth. Which of the following statements is true?

1. The measure of inertia of body A is identical with that of body B;
2. The weight of body A is identical with that of body B;
3. The weight and mass of body A are identical with those of body B;
4. All of the above;
5. None of the above.

Correct Answer: 1

2. Classificatory Statement:

The mass of a body is described as a scalar quantity.

Test Item:

In PSSC physics, which of the following statements is true?

1. The mass of a body is a vector quantity;
2. The mass of a body is a scalar quantity;
3. The weight of a body is both a scalar and a vector quantity;
4. The weight of a body is not a vector and not a scalar quantity;
5. None of the above.

Correct Answer: 2

3. Correlational Statement:

The acceleration of gravity is predicted to be the same for bodies of different material.

Test Item:

Body A and body B are at the same height above the ground. Body A is made of lead and body B is made of aluminum. The density of lead is 1.13×10^4 kg/m^3 and the density of aluminum is 2.70×10^3 kg/m^3. Which of the following statements is most correct?

1. The weight of body A is greater than that of body B;
2. Body A has a mass larger than body B;
3. The acceleration of gravity is the same for body A and body B;
4. All of the above;
5. None of the above.

Correct Answer: 3

4. Correlational Statement:

The gravitational force of a body with the earth is predicted to decrease at a rate inversely proportional to the square of the distance between the two bodies.

Test Item:

A body is weighed and found to be 10 newtons on the surface of the earth. If the earth were doubled in diameter with its mass unchanged, which of the following statements would be true?

1. The body would have a weight of 40 newtons;
2. The body would have a weight of 20 newtons;
3. The body would have a weight of 10 newtons;
4. The body would have a weight of 2.50 newtons;
5. None of the above.

Correct answer: 4

5. Inferential Statement:

From the independence of a force in one direction upon another force in a different direction, the relationship f = ma is explained.

Test Item:

A body with mass M has a weight of 10 newtons at a place on the earth where the acceleration of gravity is 9.6 m/sec/sec. To give this body the same value of acceleration in a horizontal direction, which of the following forces should be exerted on the body?

1. 10 newtons;
2. 20 newtons;
3. 0;
4. -10 newtons;
5. None of the above.

Correct Answer: 1

6. Inferential Statement:

From the relationships: Weight = $K \frac{M \times M'}{R^2}$ and $F_A = F_R$, the reaction force is explained to be two times as large as the previous action force.

Test Item:

According to the Newton's third law of motion, a force is always accompanied by a reaction force. A body has a weight of 10 newtons when weighed by a spring balance. What is the amount of the reaction force exerted on the earth if the mass of the body is doubled?

1. 20 newtons;
2. 10 newtons;
3. 0;
4. -10 newtons;
5. None of the above.

Correct Answer: 1

7. Classificatory Statement:

Measurements of a body on an equal-arm balance and a spring balance are described as belonging to two different groups: mass and weight.

Correlational Statement:

The quantity of mass is predicted as constant at different elevations and the quantity of weight as decreasing with increasing altitudes.

Test Item:

On the surface of the earth, there are body A and body B. Body A is measured by an equal-arm balance, and body B is measured by a spring balance. The measuring results are X for body A on the equal-arm balance and Y for body B on the spring balance. At an elevation of 20 km above the surface of the earth, body A and body B are measured once again by the same instruments. The second measurements are X' for body A on the equal-arm balance and Y' for body B on the spring balance. Which of the following statements is true?

1. $X = X'$ and $Y = Y'$;
2. $X > X'$ and $Y > Y'$;
3. $X > X'$ and $Y = Y'$;
4. $X = X'$ and $Y > Y'$;
5. None of the above.

Correct Answer: 4

8. Classificatory Statement:

Ounce and kilogram are described as units of mass, and distance and speed are described as the magnitudes of vectors.

Test Item:

Mass and weight of a body are two physical concepts. Into which of the following five categories can you classify them to best match, respectively, each of the two groups?

1. Group-I: 1,2,3,4, and 5;
   Group-II: 1 unit, 2 units, e units, r units, and 5 units;
2. Group-I: Distance, volume, speed, time, and energy;
   Group-II: Displacement, velocity, acceleration, momentum, and force;

3. Group-I: Ounce and kilogram;
   Group-II: Distance and speed;
4. Group-I: Photon, electric charge, and magnetic pole;
   Group-II: Pressure, electric force, and magnetic force;
5. None of the above.

Correct Answer: 3

9. Inferential Statement:

From the process of a collision, the body weight of a football player is explained as an indicator of mass.

Test Item:

A football player has a weight of 190 lb. Do you agree that in the process of blocking an opposite team player in a head-on collision with the friction between the player's body and the earth not taken into account,

1. The 190-lb weight is used as an indicator proportional to the player mass;
2. The 190 lb weight is used as a force exerted on the opposite player;
3. The 190-lb weight is used both as a force and an indicator of mass;
4. The 190-lb weight is used as a gravitational force;
5. None of the above.

Correct Answer: 1

10. Inferential Statement:

The known knowledge defined in terms of mass, weight, and volume is used to infer correlational knowledge which exists between the density and the specific gravity.

Test Item:

The density of a body is defined as its mass divided by its volume. The specific gravity of the same body is defined as its weight divided by the weight of water with the same volume as the body. Assume that 1 cubic meter of water has a weight of 9.8×10^3 newtons on the earth. Which of the following statements is true for this body in the MKS system?

1. Density = Specific gravity;
2. The unit of density = the unit of specific gravity;
3. The magnitude of density = 10^3 x the magnitude of specific gravity;
4. The magnitude of density = the magnitude of specific gravity;
5. None of the above.

Correct Answer: 3

11. Inferential Statement:

Since mass is distributed on each of the particles which constitute a body, the component weights are explained as being exerted on each of these particles with the resultant weight represented on the center of mass.

Test Item:

Analytically, a large body is composed of a great number of particles and the mass of the body is distributed in each particle. In considering the weight of the body, which of the following atatements is true?

1. Each particle in the body has no weight;
2. The particles in the body have parallel component gravitational forces;
3. The weight of the body is exerted on the center of mass of the body with each particle having no weight;
4. The resultant weight of the body is represented for calculation purposes as being exerted on the center of mass of the body;
5. None of the above.

Correct Answer: 4

12. Correlational Statement:

From the formula: $v = \sqrt{\frac{2kM}{r}}$, the escape speeds of body A and body B are predicted as being the same.

Test Item:

Body A and body B are given an initial speed to escape from the gravitational pull of the earth. Body A has a mass twice the mass of body B. Which of the following statements is true?

1. The initial speed of body A should be twice as large as the initial speed of body B;
2. The escape speed is proportional to the square root of the mass of a body;
3. The kinetic energy needed for body A to escape is the same as the kinetic energy required for body B;
4. The escape speed is the same for both body A and body B;
5. None of the above.

Correct Answer: 4

QUESTIONS ON MASS AND WEIGHT

FOR

PSSC PHYSICS STUDENTS

Name ___________________

Directions: Circle the number preceding the statement that you believe is the correct answer to each question.

For example: Which of the following statements is true? The sun sets in the:

1. North;
2. South;
3. East;
4. West.

The time limit for this test is 20 minutes.

1. Body A and body B are both 20 kg in mass and are placed at different heights above the surface of the earth. Which of the following statements is true?

    1. The measure of inertia of body A is identical with that of body B;
    2. The weight of body A is identical with that of body B;
    3. The weight and mass of body A are identical with those of body B;
    4. All of the above;
    5. None of the above.

2. In PSSC physics, which of the following statements is true?

    1. The mass of a body is a vector quantity;
    2. The mass of a body is a scalar quantity;
    3. The weight of a body is both a scalar and a vector quantity;
    4. The weight of a body is not a vector and not a scalar quantity;
    5. None of the above.

3. Body A and body B are at the same height above the ground. Body A is made of lead and body B is made of aluminum. The density of lead is 1.13×10^4 kg/m^3 and the density of aluminum is 2.70×10^3 kg/m^3. Which of the following statements is most correct?

   1. The weight of body A is greater than that of body B;
   2. Body A has a mass larger than body B;
   3. The acceleration of gravity is the same for body A and body B;
   4. All of the above;
   5. None of the above.

4. A body is weighed and found to be 10 newtons on the surface of the earth. If the earth were doubled in diameter with its mass unchanged, which of the following statements would be true?

   1. The body would have a weight of 40 newtons;
   2. The body would have a weight of 20 newtons;
   3. The body would have a weight of 10 newtons;
   4. The body would have a weight of 2.50 newtons;
   5. None of the above.

5. A body with mass M has a weight of 10 newtons at a place on the earth where the acceleration of gravity is 9.6 m/sec/sec. To give this body the same value of acceleration in a horizontal direction, which of the following forces should be exerted on the body?

   1. 10 newtons;
   2. 20 newtons;
   3. 0;
   4. -10 newtons;
   5. None of the above.

6. According to the Newton's third law of motion, a force is always accompanied by a reaction force. A body has a weight of 10 newtons when weighed by a spring balance. What is the amount of the reaction force exerted on the earth if the mass of the body is doubled?

   1. 20 newtons;
   2. 10 newtons;
   3. 0;
   4. -10 newtons,
   5. None of the above.

7. On the surface of the earth, there are body A and body B. Body A is measured by an equal-arm balance, and body B is measured by a spring balance. The measuring results are X for body A on the equal-arm balance and Y for body B on the spring balance. At an elevation of 20 km above the surface of the earth, body A and body B are measured once again by the same instruments. The second measurements are X' for body A on the equal-arm balance and Y' for body B on the spring balance. Which of the following statements is true?

   1. X = X' and Y = Y';
   2. X > X' and Y > Y';
   3. X > X' and Y = Y';
   4. X = X' and Y > Y';
   5. None of the above.

8. Mass and weight of a body are two physical concepts. Into which of the following five categories can you classify them to best match, respectively, each of the two groups?

   1. Group-I: 1,2,3,4, and 5;
      Group-II: 1 unit, 2 units, 3,units, 4 units, and 5 units;
   2. Group-I: Distance, volume, speed, time, and energy;
      Group-II: Displacement, velocity, acceleration, momentum, and force;
   3. Group-I: Ounce and kilogram;
      Group-II: Distance and speed;
   4. Group-I: Photon, electric charge, and magnetic pole;
      Group-II: Pressure, electric force, and magnetic force;
   5. None of the above.

9. A football player has a weight of 190 lb. Do you agree that in the process of blocking an opposite team player in a head-on collision with the friction between the player's body and the earth not taken into account,

   1. The 190-lb weight is used as an indicator proportional to the player mass;
   2. The 190-lb weight is used as a force exerted on the opposite player;
   3. The 190-lb weight is used both as a force and an indicator of mass;
   4. The 190-lb weight is used as a gravitational force;
   5. None of the above.

10. The density of a body is defined as its mass divided by its volume. The specific gravity of the same body is defined as its weight divided by the weight of water with the same volume as the body. Assume that 1 cubic meter of water has a weight of 9.8×10^3 newtons on the earth. Which of the following statements is true for this body in the MKS system?

    1. Density = Specific gravity;
    2. The unit of density = the unit of specific gravity;
    3. The magnitude of density = 10^3 x the magnitude of specific gravity;
    4. The magnitude of density = the magnitude of specific gravity;
    5. None of the above.

11. Analytically, a large body is composed of a great number of particles and the mass of the body is distributed in each particle. In considering the weight of the body, which of the following statements is true?

    1. Each particle in the body has no weight;
    2. The particles in the body have parallel component gravitational forces;
    3. The weight of the body is exerted on the center of mass of the body with each particle having no weight;
    4. The resultant weight of the body is represented for calculation purposes as being exerted on the center of mass of the body;
    5. None of the above.

12. Body A and body B are given an initial speed to escape from the gravitational pull of the earth. Body A has a mass twice the mass of body B. Which of the following statements is true?

    1. The initial speed of body A should be twice as large as the initial speed of body B;
    2. The escape speed is proportional to the square root of the mass of a body;
    3. The kinetic energy needed for body A to escape is the same as the kinetic energy required for body B;
    4. The escape speed is the same for both body A and body B;
    5. None of the above.

APPENDIX E

FORTRAN IV PROGRAM FOR B-COEFFICIENT CALCULATION

Fortran IV Program for B-coefficient Calculation

```
      DIMENSION R(43,43),T(43),SUM(43,43),S(43,43),A(43,43)
      INTEGER X, Y, Z
      EQUIVALENCE(R(1,1),A(1,1))
      DATA T/43*0.0/,SUM/1849*0.0/
      READ(5,100) R
 100  FORMAT(10F8.4/10F8.4/10F8.4/10F8.4/3F8.4)
      DO 400 M=1,43
      T(M)=0.0
      DO 391 N=1,43
      IF (N.EQ.M) GO TO 391
      X=M
      Y=N
      T(M)=T(M)+R(X,Y)
 391  CONTINUE
 200  WRITE(6,135)M,T(M)
 135  FORMAT(6X,'M=',I5,5X,'T(M)=',F10.5)
 400  CONTINUE
C
C
      DO 70 Z=1,42
      DO 80 I=1,43
      DO 80 K=I,43,Z
      IF(I.EQ.K) GO TO 80
      SUM(I,K)=0.0
      DO 60 L=I,K,Z
 60   SUM(I,K)=SUM(I,K)+T(L)
 44   WRITE(6,43) I, K, Z, SUM(I,K)
      FORMAT(5X,'SUM(',I3,1X,'TO',I3,1X,'WITH INTERVAL Z=',I3,1X,')=',F
     110.5)
 80   CONTINUE
      WRITE(8) SUM
 70   CONTINUE
C
C
      DO 116 Z=1,42
      DO 117 M=1,43
      DO 117 N=M,43,Z
      Y=N
      IF (Y.LT.(M+Z)) GO TO 117
      S(M,N)=0.0
 13   X=M
      S(M,N)=S(M,N)+R(X,Y)
 10   IF ((Y-X).EQ.Z) GO TO 11
      X=X+Z
      S(M,N)=S(M,N)+R(X,Y)
      GO TO 10
 11   Y=Y-Z
      IF(Y-M)13,900,13
```

```
 900    WRITE(6,34)M,N,Z,S(M,N)
 34     FORMAT(6X,'S(',I3,1X,'TO',I3,1X,'WITH INTERVAL Z=',I3,1X,')=',F10.
      15)
 117    CONTINUE
        WRITE(9) S
 116    CONTINUE
C
C
        REWIND 8
        REWIND 9
        DO 111 Z=1,42
        READ(8) SUM
        READ(9) S
        DO 112 M=1,43
        DO 112 N=M,43,Z
        IF (M.LT.(M+Z)) GO TO 112
        A(M,N)=SUM(M,N)-2.*S(M,N)
        WRITE(6,113)M,N,Z,A(M,N)
 113    FORMAT(5X,'A(',I3,1X,'TO',I3,1X,'WITH INTERVAL Z=',I3,1X,')=',F10
      1.5)
 112    CONTINUE
        WRITE(10) A
 111    CONTINUE
C
C
        REWIND 9
        REWIND 10
        DO 222 Z=1,42
        READ(9) S
        READ(10) A
        DO 223 M=1,43
        DO 223 N=M,43,Z
        IF (N.LT.(M+Z)) GO TO 223
        IF((A(M,N)+1).EQ.1) GO TO 223
        I=(((N-M)/Z)+1)
        B=(200.*(43.-I)*S(M,N))/((I-1.)*A(M,N))
        WRITE(6,224)M,N,Z,B
 224    FORMAT(5X,'B(',I3,1X,'TO',I3,1X,'WITH INTERVAL Z=',I3,1X,')=',F10.
      15)
 223    CONTINUE
 222    CONTINUE
        STOP
        END
```

APPENDIX F

LISTS OF CONCEPTUAL ELEMENTS
WITH IMPORTANCE INDICES

LIST OF PROBLEM-RELATED CONCEPTUAL ELEMENTS PERCEIVED IN MASS BY WORTHINGTON STUDENT GROUP

Item Number	Conceptual Element	Importance Index	Item Number	Conceptual Element	Importance Index
PMW01	Weight	14.080	PMW38	Energy	0.915
PMW02	Gravity	8.326	PMW39	Metric System	0.894
PMW03	Density	7.919	PMW40	Field	0.850
PMW04	Force	5.671	PMW41	Tangibility	0.800
PMW05	Gram	5.276	PMW42	Build-up	0.736
PMW06	Constant	5.078	PMW43	$F = G \frac{MM'}{R^2}$	0.727
PMW07	Matter	5.014			
PMW08	Kilogram	4.692	PMW44	Formula	0.718
PMW09	Measurement (Amount)	4.186	PMW45	Structure	0.684
			PMW46	Direction	0.600
PMW10	Scale	3.504	PMW47	Concept	0.600
PMW11	Space	3.485	PMW48	Motion	0.444
PMW12	Volume	3.404	PMW49	Error	0.384
PMW13	Kinetic Energy	3.098	PMW50	Pull	0.368
PMW14	Crowd	3.040	PMW51	Number	0.315
PMW15	Inertia	2.819	PMW52	Bulk	0.263
PMW16	Size	2.795	PMW53	Vector	0.153
PMW17	Science	2.698	PMW54	Particle	0.090
PMW18	Balance	2.442	PMW55	Light	0.071
PMW19	Scalar	2.400	PMW56	Atom	0.066
PMW20	Newton	2.344			
PMW21	Momentum	2.267			
PMW22	Velocity	1.867			
PMW23	Altitude	1.846			
PMW24	Earth	1.835			
PMW25	Pound	1.830			
PMW26	Conservation of Mass	1.723			
PMW27	Solid	1.705			
PMW28	Acceleration	1.678			
PMW29	Speed	1.603			
PMW30	Physics	1.557			
PMW31	Body	1.478			
PMW32	Universe	1.273			
PMW33	F = ma	1.225			
PMW34	Substance	1.104			
PMW35	Heavy	0.971			
PMW36	Molecule	0.946			
PMW37	Attraction	0.923			

LIST OF PROBLEM-NONRELATED CONCEPTUAL ELEMENTS PERCEIVED IN MASS BY WORTHINGTON STUDENT GROUP

Item Number	Conceptual Element	Importance Index	Item Number	Conceptual Element	Importance Index
NMW01	Potential Energy	1.525	NMW41	Work	0.111
NMW02	Displacement	1.100	NMW42	Group	0.095
NMW03	Man	1.000	NMW43	Pew	0.086
NMW04	Area	1.000	NMW44	Fat	0.066
NMW05	Catholic	0.925	NMW45	Religion	0.047
NMW06	Liquid	0.916			
NMW07	Object	0.916			
NMW08	Weightlessness	0.800			
NMW09	Gravitational Mass	0.789			
NMW10	Atmosphere	0.750			
NMW11	Church	0.685			
NMW12	Specific Gravity	0.600			
NMW13	Chemistry	0.600			
NMW14	Stars	0.557			
NMW15	Time	0.545			
NMW16	Pope	0.523			
NMW17	Electron	0.514			
NMW18	Rate	0.500			
NMW19	Moon	0.500			
NMW20	Large (huge)	0.486			
NMW21	Commune	0.476			
NMW22	Sun	0.450			
NMW23	Standards	0.428			
NMW24	Baptism	0.380			
NMW25	Proton	0.363			
NMW26	Mob	0.333			
NMW27	A Great Many	0.300			
NMW28	Christmas	0.286			
NMW29	Priest	0.260			
NMW30	Swinging	0.250			
NMW31	Dimension	0.227			
NMW32	Pressure	0.222			
NMW33	Confession	0.217			
NMW34	Lecturing	0.200			
NMW35	Bishop	0.190			
NMW36	Midnight Mass	0.173			
NMW37	Preacher	0.150			
NMW38	Experiment	0.150			
NMW39	Advent	0.142			
NMW40	Prayer	0.130			

LIST OF PROBLEM-RELATED CONCEPTUAL ELEMENTS PERCEIVED IN WEIGHT BY WORTHINGTON STUDENT GROUP

Item Number	Conceptual Element	Importance Index	Item Number	Conceptual Element	Importance Index
PWW01	Mass	13.665	PWW40	Mathematics	0.437
PWW02	Gravity	12.794	PWW41	Water	0.421
PWW03	Scale	9.670	PWW42	Solid	0.368
PWW04	Pound	6.728	PWW43	Error	0.286
PWW05	Balance	6.598			
PWW06	Force	6.482			
PWW07	Heavy	4.486			
PWW08	Substance	4.176			
PWW09	Density	4.026			
PWW10	Variation	4.012			
PWW11	Altitude	3.968			
PWW12	Size	3.833			
PWW13	Gram	3.735			
PWW14	Light	3.525			
PWW15	Newton	3.167			
PWW16	Attraction	3.089			
PWW17	Measurement	2.334			
PWW18	Kilogram	2.327			
PWW19	Volume	2.289			
PWW20	Thickness	1.739			
PWW21	Earth	1.635			
PWW22	Spring Scale	1.518			
PWW23	Motion	1.234			
PWW24	Sea Level	1.129			
PWW25	Speed	1.110			
PWW26	Reality	1.013			
PWW27	$W = G \frac{MM'}{R^2}$	1.000			
PWW28	Tangibility	0.869			
PWW29	Unit	0.714			
PWW30	Standards	0.687			
PWW31	Formula	0.625			
PWW32	Direction	0.611			
PWW33	Magnitude	0.578			
PWW34	Physics	0.562			
PWW35	Existence	0.533			
PWW36	Specific Gravity	0.526			
PWW37	Weight Loss or Gain	0.489			
PWW38	Resistance	0.478			
PWW39	Work	0.475			

LIST OF PROBLEM-NONRELATED CONCEPTUAL ELEMENTS PERCEIVED IN WEIGHT BY WORTHINGTON STUDENT GROUP

Item Number	Conceptual Element	Importance Index	Item Number	Conceptual Element	Importance Index
NWW01	Ounce	3.335	NWW39	Moon	0.111
NWW02	Ton	2.893	NWW40	Boxing	0.111
NWW03	Potential Energy	1.307	NWW41	Wrestling	0.095
NWW04	Magnetic Attraction	1.104	NWW42	Justice	0.086
			NWW43	Weightlessness	0.076
NWW05	Huge	1.072	NWW44	Wait	0.071
NWW06	Fat	1.047	NWW45	Body Weight	0.052
NWW07	Lifting	0.983	NWW46	Muscle	0.043
NWW08	Calories	0.944			
NWW09	Place	0.888			
NWW10	Concept	0.826			
NWW11	Skinny	0.823			
NWW12	Thin	0.781			
NWW13	Dimension	0.733			
NWW14	Monstrous	0.672			
NWW15	Pressure	0.642			
NWW16	Kinetic Energy	0.631			
NWW17	Feather	0.604			
NWW18	Displacement	0.600			
NWW19	Average	0.565			
NWW20	Under	0.521			
NWW21	Science	0.500			
NWW22	Small	0.475			
NWW23	Middle	0.419			
NWW24	Inertia	0.333			
NWW25	Football	0.308			
NWW26	Physical Exercise	0.305			
NWW27	Grand	0.304			
NWW28	Eating	0.285			
NWW29	Obese	0.285			
NWW30	Over	0.260			
NWW31	Repel	0.250			
NWW32	Welterweight	0.214			
NWW33	Evaporation	0.200			
NWW34	Shotput	0.190			
NWW35	Metal	0.182			
NWW36	Fly	0.173			
NWW37	Weight-watch	0.142			
NWW38	Respiration	1.133			

LIST OF PROBLEM-RELATED CONCEPTUAL ELEMENTS PERCEIVED IN MASS BY TAIWAN STUDENT GROUP

Item Number	Conceptual Element	Importance Index
PMT01	Weight	11.279
PMT02	Gravity	10.194
PMT03	Conservation of Mass	9.113
PMT04	Balance	7.009
PMT05	Substance	6.854
PMT06	Constant	6.174
PMT07	Acceleration	5.819
PMT08	Inertia	5.756
PMT09	Density	5.712
PMT10	Measurement	4.937
PMT11	Scale	4.461
PMT12	Gram	3.900
PMT13	Center of Mass	3.776
PMT14	Matter	3.650
PMT15	F = m x a	3.406
PMT16	Scalar	3.311
PMT17	Physics	3.146
PMT18	Unit	2.986
PMT19	Kinetic Energy	2.917
PMT20	Momentum	2.847
PMT21	Force	2.609
PMT22	Velocity	2.501
PMT23	Calculation	2.442
PMT24	Volume	2.366
PMT25	Conservation of Energy	2.258
PMT26	Kilogram	1.944
PMT27	Motion	1.928
PMT28	Newton	1.918
PMT29	$E = mc^2$	1.711
PMT30	Proton	1.648
PMT31	Potential Energy	1.411
PMT32	Reaction Force	1.285
PMT33	Molecule	1.218
PMT34	Vector	1.105
PMT35	Newton's Laws	1.066
PMT36	Pound	1.017
PMT37	Heavy	1
PMT38	Particle	1.000
PMT39	Body Weight	0.993
PMT40	Equipment	0.956
PMT41	Size	0.950
PMT42	Concept	0.930
PMT43	Earth	0.905
PMT44	Space	0.894
PMT45	Moon	0.882
PMT46	Atmosphere	0.875
PMT47	Spring	0.842
PMT48	Time	0.842
PMT49	Mechanics	0.833
PMT50	Existence	0.801
PMT51	Relativity	0.767
PMT52	Escape Energy	0.766
PMT53	Quality	0.751
PMT54	Apple	0.749
PMT55	Light	0.688
PMT56	Weightlessness	0.651
PMT57	Electron	0.634
PMT58	Spring Balance	0.611
PMT59	Displacement	0.465
PMT60	Loss	0.351
PMT61	Attraction	0.315
PMT62	Radius	0.263
PMT63	Lifting	0.230
PMT64	Metal	0.228
PMT65	Vacuum	0.212
PMT66	Gravitational Mass	0.133

LIST OF PROBLEM-NONRELATED CONCEPTUAL ELEMENTS PERCEIVED IN MASS BY TAIWAN STUDENT GROUP

Item Number	Conceptual Element	Importance Index	Item Number	Conceptual Element	Importance Index
NMT01	Hook's Law	1.766	NMT15	Mass Number	0.437
NMT02	Specific Gravity	1.635	NMT16	Newton	0.423
NMT03	Impulse	1.147	NMT17	m	0.421
NMT04	Velocity of Light	1.038	NMT18	Center of Gravity	0.315
NMT05	Atom	1.009	NMT19	Pressure	0.294
NMT06	Chemistry	0.976	NMT20	External	0.279
NMT07	Escape Velocity	0.966	NMT21	Internal	0.278
NMT08	Matter Properties	0.883	NMT22	Length	0.276
NMT09	Einstein	0.869	NMT23	Accuracy	0.230
NMT10	Sun	0.833	NMT24	Market	0.200
NMT11	Definition	0.800	NMT25	Temperature	0.187
NMT12	Speed	0.625	NMT26	Specific Heat	0.176
NMT13	Oil Drop Experiment	0.596	NMT27	Work	0.166
			NMT28	Meter	0.166
NMT14	Archimedes' Principle	0.454	NMT29	Height	0.083
			NMT30	Power	0.010

LIST OF PROBLEM-RELATED CONCEPTUAL ELEMENTS PERCEIVED IN WEIGHT BY TAIWAN STUDENT GROUP

Item Number	Conceptual Element	Importance Index	Item Number	Conceptual Element	Importance Index
PWT01	Gravity	11.291	PWT38	Equipment	1.356
PWT02	Spring Balance	11.137	PWT39	Moon	1.333
PWT03	Mass	9.137	PWT40	Ton	1.161
PWT04	Body Weight	7.247	PWT41	Work	1.147
PWT05	Non-constant	6.760	PWT42	Vacuum	1.039
PWT06	Kilogram	5.870	PWT43	Concept	1.000
PWT07	Unit	5.073	PWT44	Hammer	0.989
PWT08	Earth	4.939	PWT45	Calculations	0.945
PWT09	mg	4.760	PWT46	Escape Energy	0.883
PWT10	Substance	4.603	PWT47	Momentum	0.875
PWT11	Altitude	4.507	PWT48	Recoil	0.800
PWT12	Scale	4.491	PWT49	Potential Energy	0.687
PWT13	Specific Gravity	4.323	PWT50	Motion	0.631
PWT14	Balance	4.260	PWT51	Wreck	0.525
PWT15	$W = G \frac{MM'}{R^2}$	3.812	PWT52	Time	0.500
			PWT53	Animal	0.357
PWT16	Heavy	3.771	PWT54	Escape Speed	0.250
PWT17	Volume	3.567	PWT55	Rest Situation	0.250
PWT18	Physics	3.447	PWT56	Pound	0.249
PWT19	Vector	2.894	PWT57	Gram	0.011
PWT20	Size	2.577			
PWT21	Field	2.566			
PWT22	Weightlessness	2.498			
PWT23	Light	2.447			
PWT24	Newton	2.374			
PWT25	Pressure	2.343			
PWT26	Definition	2.304			
PWT27	Metal	2.245			
PWT28	Force	2.217			
PWT29	Density	2.161			
PWT30	Spring	2.101			
PWT31	Attraction	2.080			
PWT32	Acceleration	1.835			
PWT33	Number	1.725			
PWT34	Newton's Law	1.661			
PWT35	Lifting	1.451			
PWT36	Center of Gravity	1.395			
PWT37	Velocity	1.365			

LIST OF PROBLEM-NONRELATED CONCEPTUAL ELEMENTS PERCEIVED IN WEIGHT BY TAIWAN STUDENT GROUP

Item Number	Conceptual Element	Importance Index	Item Number	Conceptual Element	Importance Index
NWT01	Water	2.357	NWT17	Market	0.434
NWT02	Fat	1.866	NWT18	Non-equilibrium	0.432
NWT03	Atmosphere	1.858	NWT19	Bouncing	0.382
NWT04	Buoyancy	1.671	NWT20	Internal	0.324
NWT05	Fist	1.382	NWT21	Shell	0.300
NWT06	Matter Properties	1.073	NWT22	External	0.291
NWT07	Real Weight	1.058	NWT23	Racing	0.268
NWT08	Apparent Weight	0.944	NWT24	Solid	0.230
NWT09	Feather	0.851	NWT25	Solar System	0.214
NWT10	Oil Drop Experiment	0.832	NWT26	Price	0.189
			NWT27	Area	0.166
NWT11	Friction	0.700	NWT28	Pressure	0.150
NWT12	Thin	0.675	NWT29	Ambiguity	0.121
NWT13	Rocket	0.650	NWT30	Apple	0.071
NWT14	Atwood Machine	0.642	NWT31	Swimming	0.055
NWT15	Aircraft	0.500	NWT32	Graduation	0.052
NWT16	Radius	0.461	NWT33	Diet	0.027

APPENDIX G

SUMMARY OF MEANS AND STANDARD DEVIATIONS IN TWO-WAY ANALYSIS OF VARIANCE

SUMMARY TABLE FOR MEANS AND STANDARD DEVIATIONS IN
TWO-WAY ANALYSIS OF VARIANCE

Factor	Mean	Standard Deviation
Total Number of Conceptual Elements		
High Achievement - Worthington	26.89	8.24
High Achievement - Taiwan	35.22	12.90
Low Achievement - Worthington	31.30	9.39
Low Achievement - Taiwan	36.10	18.08
Number of Problem-related Conceptual Elements		
High Achievement - Worthington	20.55	7.16
High Achievement - Taiwan	25.11	8.73
Low Achievement - Worthington	17.90	6.62
Low Achievement - Taiwan	26.20	13.83
Number of Problem-nonrelated Conceptual Elements		
High Achievement - Worthinton	6.33	5.19
High Achievement - Taiwan	10.11	8.17
Low Achievement - Worthington	13.40	6.85
Low Achievement - Taiwan	9.90	10.06
Number of Physical Science Conceptual Elements		
High Achievement - Worthington	18.22	5.84
High Achievement - Taiwan	27.00	9.27
Low Achievement - Worthington	19.30	6.78
Low Achievement - Taiwan	27.20	10.93
Number of Everyday Conceptual Elements		
High Achievement - Worthington	8.66	6.76
High Achievement - Taiwan	6.00	5.61
Low Achievement - Worthington	12.00	6.30
Low Achievement - Taiwan	9.40	11.35

(Continued on next page)

Summary Table - Means and Standard Deviations. (Continued)

Factor	Mean	Standard Deviation
Number of Additional Conceptual Elements		
High Achievement - Worthington	2.00	1.93
High Achievement - Taiwan	6.55	4.97
Low Achievement - Worthington	2.00	2.21
Low Achievement - Taiwan	5.40	6.24
Number of Deleted Conceptual Elements		
High Achievement - Worthington	5.88	5.34
High Achievement - Taiwan	4.66	6.38
Low Achievement - Worthington	7.30	3.85
Low Achievement - Taiwan	8.20	10.83
Importance of Problem-related Conceptual Elements		
High Achievement - Worthington	0.87	0.11
High Achievement - Taiwan	0.78	0.15
Low Achievement - Worthington	0.72	0.15
Low Achievement - Taiwan	0.82	0.17
Importance of Problem-nonrelated Conceptual Elements		
High Achievement - Worthington	0.12	0.11
High Achievement - Taiwan	0.21	0.15
Low Achievement - Worthington	0.27	0.15
Low Achievement - Taiwan	0.18	0.17
Number of Overlapping Conceptual Elements		
High Achievement - Worthington	3.55	2.69
High Achievement - Taiwan	3.88	2.20
Low Achievement - Worthington	4.50	3.34
Low Achievement - Taiwan	4.40	2.98

(Continued on next page)

Summary Table - Means and Standard Deviations. (Continued)

Factor	Mean	Standard Deviation
Number of Exclusive Conceptual Elements		
High Achievement - Worthington	19.77	6.76
High Achievement - Taiwan	28.33	10.00
Low Achievement - Worthington	22.30	7.46
Low Achievement - Taiwan	27.30	14.13
Number of Correct Uses of Conceptual Elements		
High Achievement - Worthington	53.88	24.53
High Achievement - Taiwan	54.88	54.61
Low Achievement - Worthington	23.10	15.70
Low Achievement - Taiwan	46.30	44.20
Number of Incorrect Uses of Conceptual Elements		
High Achievement - Worthington	51.00	27.42
High Achievement - Taiwan	21.22	16.43
Low Achievement - Worthington	59.30	22.58
Low Achievement - Taiwan	45.00	31.85

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