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ABSTRACT

After opening with a 13-page review of the literature, the document's main emphasis is on the three experiments included in this report. The specific rationale, procedures, and results of the three studies comprise the major portion of the document. The general purpose of Experiment 1 was to ascertain the effects of prior relevant subject matter knowledge, differentially structured introductory learning materials, and differentially sequenced learning tasks on learning acquisition and transfer. Experiment 2 determined the extent to which self-regard and learning performance are influenced by the type and extent of feedback received during stages of a mathematical learning activity. Differential performance by men and women was also investigated. The purpose of Experiment 3 was to find the effects of presenting sets of introductory mathematical learning materials which are differentially structured with respect to a concrete-abstract dimension. The effects of the adult learner's subject matter background and sex on learning and transfer were also investigated. The results of the three experiments are presented graphically and discussed in detail. Included also are a 39-item bibliography and seven appendixes containing pretests, posttests, and a personal significance scale. (BP)

FINAL REPORT

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INFLUENCE OF COGNITIVE AND AFFECTIVE FACTORS ON ADULT LEARNING THREE EXPERIMENTAL STUDIES

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Influence of Cognitive and Affective Factors on Adult Learning: Three Experimental Studies

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June 1, 1972

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A.D.G.

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INTRODUCTION

The effects of prior learning on subsequent learning have been demonstrated by a large number of research studies dealing with infra-human as well as human pre-adult subjects. In the field of adult learning as well, the fact that previous educational experience affects the learning of adults is acknowledged by researchers of the adult learning process, teachers of adults, and adult learners themselves who are engaged in formal educational activities. The influence of the educational background of the adult education participant on learning outcomes has been investigated by various researchers (e.g., Sorenson, 1930; Sjogren and Knox, 1965, 1967). Findings from these studies suggest that adults who have not recently participated in an educational activity or who do not have a high level of formal educational background are not able to perform as well in a learning situation as those who have recently been involved in some educational activity or who have a high level of formal education. As a result, the adult with an inadequate educational background frequently becomes dissatisfied and drops out of the activity. Furthermore, the varied educational backgrounds of students in many adult education classes makes it difficult for the instructor to arrange the external conditions of learning.

An approach by which the instructor may influence variables relevant to learning outcomes, places emphasis on the structure and sequencing of a body of knowledge.[1] To facilitate learning, background information is given to the learner through a process that includes the appropriate selection of subject matter which is effectively sequenced.

It is recognized that some learner characteristics will ordinarily influence the achievement of desired learning outcomes. However, it is also important to consider the characteristics of the instructional activity which affect learning. Knowledge about the effectiveness of instructional activity, combined with information about learner characteristics, should result in the design of a more effective educational experience for adults.

The Problem

An important task of the educator is to present the optimal structure and sequence of educative activities. For example, the classroom teacher is concerned with the selection, organization, and presentation of a subject matter in the form of lessons, units, and courses. The curriculum specialist, too, is concerned with the design of an educative experience which is deliberately structured and sequenced in a manner that facilitates the achievement of intended objectives. Other educators, such as the programed learning specialist, the author of educational

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[1]The term *structure* refers to the content and organization of a selected subject matter, and *sequence* refers to the sequential arrangement in which the content is presented. (This distinction is somewhat similar to the familiar curriculum concepts of scope and sequence.)

texts and materials, and the educational psychologist have recently placed increased emphasis on the efficient programming of educational materials.

Learning theorists have also emphasized that the structure and sequence of the educative activity have an effect on the outcomes of learning. The appropriate sequential arrangement of the learning material, within a topic to be learned and among the topics that make up a subject matter, is viewed as a requirement for effective learning. For example, both behavioristic and cognitive learning theorists assert that the sequential arrangement of the subject matter is an important variable in the study of learning.

The behavioristic viewpoint, as exemplified by Skinner and linear programmed instruction, emphasizes the psychological step-by-step sequencing of the subject matter. Through appropriate sequential arrangement of the subject matter the learner is guided progressively to a desired outcome.

Cognitive theorists, such as Ausubel, Gagne, and Bruner also emphasize the necessity of sequential arrangements of the subject matter and, in effect, advocate programming the learning material. Furthermore, they emphasize the importance of the structure of a subject matter (cf., Ausubel, 1963b; Bruner, 1960, 1964; Gagne, 1965). Also, cognitive theorists stress the assumption that subject matter which is appropriately structured and sequenced not only is more readily learned, but also becomes an important independent variable which influences the subsequent learning of related material (Ausubel, 1965). Hence, in the latter instance, one may theorize that meaningful learning can be brought about most effectively and efficiently by the manipulation of the structure and sequence of selected subject matter.

Two general procedures have been identified by Ausubel (1963b, 1965) whereby *cognitive structure* (i.e., the learner's existing organized body of knowledge regarding a learning topic) can be influenced so as to facilitate the learning of new material. One such variable is the structure of the subject matter itself. This refers to those *substantive* aspects of the subject matter that have the greatest generalizability, inclusiveness, and relatability within that subject matter area. The second variable is concerned with the manner in which the subject matter is presented, arranged, and ordered. This proper sequence of activities in which a learner is involved is referred to as the *programmatic* aspect of presenting material.

The general purpose of the reported investigations, then, was to experimentally manipulate two aspects of the instructional process, both of which serve to influence adult learning. More specifically, the purpose was to ascertain the effects of introductory materials, which are differentially structured with regard to content, on conceptually related learning tasks which are differentially sequenced.

The first variable to be manipulated was the structure of the introductory learning material presented to the learner prior to the actual learning task. This variable was manipulated for the purpose of ascertaining the effects on learning which accompany the variation of the substantive aspect of the subject matter. The second variable was manipulated to examine the influence of the sequential arrangement of the learning material on learning outcomes (i.e., the manipulation of a programmatic variable).

Theoretical Background

One of the primary proponents of the recent emphasis on the structure and sequencing of learning materials and of knowledge has been David P. Ausubel. Because the impetus and the conceptual framework for the studies herein described were basically derived from the theoretical concepts of meaningful verbal learning, as presented in various publications by Ausubel (e.g., 1961, 1962, 1963a, 1963b, 1965, 1966), a summary of this theory is necessary. Following this section on theoretical background, a review of the empirical literature on this topic is included as a background for the more specific problems of the actual research investigations.

Although the major aspects of Ausubel's cognitive theory will be summarized, there are three areas which are particularly relevant to the purposes of the three experiments reported in this document. These areas include (a) the systematic change in extent and type of knowledge brought about by the integration and incorporation of new information into the learner's existing cognitive structure; (b) the identification of those factors that have an effect on the acquisition of new information; and (c) the manipulation of the learner's cognitive structure so that the acquisition of newly presented information is enhanced.

In general, this theory is limited to various principles regarding the integration and organization of the learner's knowledge, and to various procedures whereby knowledge is acquired, retained, and forgotten. Within this frame of reference, Ausubel further limits his theory to meaningful verbal reception learning, which he believes is the most characteristic type of school learning. Reception or expository learning, as contrasted with discovery learning, refers to learning material that is presented in its entirety to the learner. Thus, the entire content to be learned is given to the learner, who only needs to internalize the material presented to him for future reproduction.

For reception learning to take effect, it is assumed that the learner possesses a mature cognitive structure. That is, the learner understands the concepts and principles of the meaningfully presented material without any necessary prior concrete experience with the material. This is in direct contrast to learning characteristics of young learners who need relevant concrete experiences directly prior to their understanding any abstract learning material (Inhelder and Piaget, 1958). Furthermore, because the reception type of learning is presented verbally, it may be presented in either a rote or a meaningful manner without prior nonverbal and problem solving experiences. It is important, therefore, to note that Ausubel's emphasis is on meaningful reception learning and not on rote learning.

Meaningful learning refers primarily to a learning process rather than a learning outcome, and is distinguished from the process of rote learning. It assumes that the learner possesses an expectation that the learning material will be meaningful to him and that the learning material actually is potentially meaningful to him. The meaningful expectation or set that is a requisite for the occurrence of meaningful learning serves to relate the substantive aspects of the learning material to relevant elements of the learner's existing cognitive structure. Obviously, the meaningful set to learn results in meaningful learning only when the material to be learned is potentially meaningful.

For learning material to be potentially meaningful, two important criteria must be satisfied. The first criterion is the non-arbitrary relatability of the learning material to relevant concepts in the potential learner's cognitive structure. This criterion applies only to the total learning material itself and not to the component parts. The second criterion involves the relatability of the learning material to the cognitive structure of a specific learner. This second criterion refers to a characteristic of the learner, whereas, the first criterion has reference to a characteristic of the learning material.

Learning materials which satisfy the criteria of potential meaningfulness are learned according to principles of learning and retention that are quite different from materials learned by rote. Meaningfully learned materials are related and anchored to an existing ideational system within the cognitive structure of the learner. In contrast, materials learned by rote are discrete entities relatable to cognitive structure in an arbitrary manner, and as a consequence are not anchored to any existing ideational system. Therefore, the meaningfully learned material is more effectively learned and has greater stability, retention, and transferability.

For potentially meaningful material to become actually meaningful, it must interact with, and be subsumed or incorporated into, the learner's existing ideational system. For this to occur, it is assumed that the content of the field of knowledge which is being learned is organized and that the relevant content within the learner's cognitive structure is also organized. First, it is assumed that the subject matter of which the potentially meaningful material is a part, is organized in some hierarchical fashion. Second, it is assumed that the organization of the learner's cognitive structure is also hierarchically organized. Within the learner's cognitive structure the most general or inclusive concepts are located at the apex of the structure under which are subsumed the less inclusive concepts and specific information.

The fact that the potentially meaningful material has interacted with and is relatable to organized conceptual and ideational elements in the learner's cognitive structure is the basis for its meaningfulness. As the new material is introduced into the learner's cognitive structure, the initial efforts of the subsumption process involve various orienting, relational, and cataloging operations. These operations are necessary for learning and retention because they provide the mechanisms whereby new material is subsumed and incorporated within the existing cognitive structure of the learner. Furthermore, anchorage within the ideational system is provided for the newly learned material. That is, newly learned material is attached to or subsumed by related concepts in cognitive structure. As a result, the newly learned material, for some variable time period, remains a separate and distinct entity within the learner's subsuming ideational system. Thus the material can be separated from its subsumer and recalled by the learner.

Although anchorage of the newly learned material within the learner's ideational system enhances its stability and retention, the material in time loses its individual identity. According to Ausubel, this is brought about by a conceptualizing trend in cognitive structure whereby less inclusive concepts and information are subsumed into more highly inclusive concepts. When this second or obliterative stage of the subsumption process begins, the specific identifiable elements of the learned material gradually become less separable from the learner's existing ideational system until they no longer have any distinct identity of their own. At this point the material is said to be forgotten.

Within meaningful reception learning the process of subsumption, therefore, is theorized to be responsible for (a) the acquisition of knowledge, (b) the stability and retention of newly acquired material, (c) the hierarchical organization of the body of knowledge within the learner's cognitive structure, and (d) the occurrence of forgetting.

Two different types of subsumption theoretically occur in the learning and retention of meaningful material. The meaningful material which is subsumed and related to existing conceptual elements may be either derived from or correlated to established concepts in the learner's cognitive structure. If new learning material is an example or illustration of some established concept or idea in the learner's cognitive structure, it is derivable from or implicit in a more inclusive concept of the established subsumer. The outcome of this type of subsumption is manifest in the easy and quick acquisition of meaning, and in rapid forgetting. The reason for rapid acquisition and forgetting is that the meaning of the new material is highly relatable to a more inclusive concept in the learner's existing cognitive structure. This inclusive concept readily subsumes the meaning of the material so that the identifiable elements of the learned material are lost. Although the learned material loses its specific identity, the material is not entirely forgotten because substantive ideas of the learned material are maintained within relevant subsumers in the learner's cognitive structure.

On the other hand, if new material is an extension, qualification, or elaboration of an established concept in the learner's cognitive structure, then it is defined as correlated to a more inclusive established subsumer. The incorporation and interaction of the meaning of this new material, which is only tangentially related to the more inclusive subsumer, is not implicit in and cannot be adequately represented by the existing subsumption system. As a consequence, newly learned material which is correlated with existing concepts which are more highly inclusive, undergoes obliterative subsumption in a way that is similar to derivatively subsumed material. The effects of obliterative subsumption are, however, more serious in the case of correlated materials. The reason for this is that when correlated materials lose their identity and can no longer be separated from their subsumers, the substance of the correlated material is not adequately represented within the subsumer and, therefore, cannot be reproduced in the future. Therefore, in this instance, the entire substance of what was learned is lost. Needless to say, obliterative subsumption occurs most rapidly when the existing conceptual subsumers are not stable and clear and when the learning material has not been overlearned.

In summary, the subsumption of potentially meaningfully derivative and correlated material is dependent upon an existing hierarchical organization of meaningfully learned materials in the learner's cognitive structure. This subsumption process efficiently reduces the new material to a least common denominator of relevant established meanings.

Ausubel theorized that learning and retention of derivative and correlated materials is influenced, in the narrow sense, by relevant subsuming concepts in the learner's cognitive structure; and, in the general sense, by the learner's subject matter knowledge. In either instance, a clear, stable, and organized existing cognitive structure will enhance the learning and retention of new relevant material. Ausubel also theorized that the extent to which transfer occurs is dependent upon the influence of these *cognitive variables* (i.e., the clarity, stability, and organization of a learner's knowledge in a subject matter). Hence the strengthening of these relevant aspects of cognitive structure will facilitate new learning, retention, and transfer.

The acquisition of an adequate cognitive structure which facilitates new learning is dependent upon two factors. One factor is the structure of the subject matter itself. This refers to those *substantive* aspects of the subject matter that have the greatest generalizability, inclusiveness, and relatability within that subject matter area. The second factor is the manner in which the subject matter is presented, arranged, and ordered. This proper sequence of activities in which a learner is involved is referred to as the *programmatic* aspect of presenting material.

Thus, Ausubel theorizes that cognitive structure is influenced by substantive and programmatic factors of the subject matter. These factors facilitate the acquisition, retention, and subsequent transfer of ideas and concepts in newly learned material.

Two principles are hypothesized to have a significant role in the sequential arrangement of learning materials. These principles, which have a marked influence on cognitive structure, are the principles of progressive differentiation and integrative reconciliation. According to the principle of progressive differentiation the most general and inclusive concepts in an area of subject matter are presented first to the learner. This is followed by content which is increasingly differentiated with regard to detail and specificity.

This order of presentation corresponds to the assumptions presented earlier regarding the organization of a subject matter area and the organization of that subject within the learner's cognitive structure. Thus if the organization of a body of knowledge and the organization of knowledge in cognitive structure conform to the principle of progressive differentiation, it is assumed that effective learning occurs. The acquisition of new material is dependent upon the availability of generalized relevant concepts in the learner's cognitive structure whose function it is to incorporate and subsume the new material.

The principle of integrative reconciliation refers to the process of relating newly acquired information to previously acquired material. By applying this principle in the programming of new learning material, ideas and concepts are integrated and reconciled with previously learned content in cognitive structure. As a consequence, relationships between ideas are more easily discovered, ideational similarities and differences are made evident, and the resolution of real or apparent inconsistencies is achieved. This procedure is in striking contrast to the common practice of presenting the ideas and content in learning material in segregated and compartmental segments.

In summary, Ausubel's theory of meaningful reception learning is based on the premise that if an individual's existing cognitive structure in a particular subject matter area is clear, stable, and organized, then the learning and retention of new meaningful material is enhanced. On the other hand, if the existing cognitive structure is ambiguous, unstable, and disorganized, then the learning and retention of new meaningful material is inhibited. As a result, attention should be directed to the strengthening of relevant aspects of the learner's cognitive structure in a subject matter area so that new learning and retention can be facilitated.

The following section presents findings from a number of experimental research investigations, in which deliberate attempts were made to influence the learner's cognitive structure so that meaningful learning would be maximized.

Related Literature

To test this complex theory, an experimental study by Ausubel (1960) hypothesized that the learning and retention of unfamiliar but meaningful verbal material could be facilitated by the introduction of advance organizers prior to the actual presentation of the learning task. This hypothesis was based on the assumption that if the introductory material made relevant and inclusive subsumers available to the learner, then these subsumers would provide an ideational framework for the incorporation and retention of more specific material inherent in the subsequent learning task.

Control and experimental groups of college undergraduates were matched according to sex, ability to learn unfamiliar scientific material, and academic field of specialization. Forty-eight hours prior to and immediately prior to studying a 2,500 word learning passage dealing with the metallurgical properties of plain carbon steel, the control and experimental groups studied a 500 word introductory passage. The experimental introductory passage contained highly abstract and inclusive background information about the learning material. It was designed as an organizer for the steel learning passage, and it served to relate the learning material to the learner's existing cognitive structure. The control introductory passage presented historical information about the methods used in processing iron and steel. A multiple choice test was administered to both groups three days after the learning passage was studied.

Significant differences between the means of the control and experimental groups supported the hypothesis that the use of highly abstract and inclusive introductory material in the teaching of meaningful verbal material would facilitate retention.

To further test the effects of stable and clear subsuming concepts in cognitive structure and the discriminability of the new learning material from its subsumers, Ausubel and Fitzgerald (1961b) hypothesized that advance organizers used to discriminate between new material and related material already established in the learner's cognitive structure would facilitate the learning and retention of the new material. Three groups of university undergraduate subjects studied one of three 500 word organizers two days before studying a 2,500 word passage on Buddhism. One experimental group studied a passage that compared the major ideas of Buddhism and Christianity; a second group studied an exposition on the principal Buddhist doctrines, without any reference to Christianity; and the third group, a control group, studied historical material about Buddha and Buddhism. In the analysis, subjects in each of the three treatment groups were divided into above- and below-median subgroups according to their knowledge of Christianity.

The results indicated that subjects with greater background knowledge scored significantly higher on the Buddhism retention scores than subjects with less knowledge of Christianity. Also, after three days, the retention of the Buddhism material was significantly better for the group that received the comparative introductory treatment. After 10 days, the subjects exposed to the comparative and expository organizers did significantly better than the group that had studied the historical introduction. The difference obtained by the facilitating effects of the organizers, however, only applied to the subgroups of learners who had achieved below-median scores on the Christianity pretest.

Ausubel and Fitzgerald concluded that advance organizers appeared to increase discrimination of unfamiliar material for learners when existing relevant concepts in cognitive structure were not clear and stable.

In a subsequent study, Ausubel and Fitzgerald (1962) studied the effects of an expository advance organizer, antecedent learning, and general background knowledge on the learning and retention of two unfamiliar sequential passages dealing with the endocrinology of pubescence.

Subjects were predominantly university seniors. At the first experimental session, the experimental group studied a 500 word expository passage that was structured to provide an organizational framework for the first learning passage, and the control group studied a 500 word introductory passage which had no organizational properties in relation to the first learning passage. Two days after the first experimental session, both experimental and control groups restudied their respective introductory passages and then studied a 1,400 word passage on the specific hormonal factors initiating and regulating pubescence. A test on the 1,400 word passage was administered two days later. Three days later the second learning passage, a 1,600 word description of pathological variations in pubescence and their treatment, was administered, and after four days the subjects were tested on the second passage.

Results indicated that the organizer facilitated the learning and retention of the first pubescence passage for those subjects with low verbal ability or those subjects with a higher endocrinology background. Knowledge of the first passage had a significant facilitating effect on learning the second passage when general background knowledge of the subject matter and verbal ability were statistically controlled. Finally, with verbal ability statistically controlled general background knowledge in endocrinology facilitated the learning of the unfamiliar material in a similar subject matter area, presumably by increasing its general familiarity.

Furthermore, Ausubel and Youssef (1963) hypothesized that (a) the discriminability of new material from previously learned material is a function of the clarity and stability of the previously learned material, and (b) an advance organizer increases the discriminability of new material from previously learned related material. It was predicted that the facilitative effects of the advance organizer would be observed with subjects who either have low verbal ability or whose relevant cognitive structure is unstable and unclear.

Undergraduate university students who were classified within two experimental treatments studied two 500 word comparative organizers before studying 2,500 word passages dealing with the principal concepts of Buddhism and Zen Buddhism, respectively. The first comparative organizer pointed out similarities and differences between Christian and Buddhist doctrines, and the second organizer performed the same function for Buddhist and Zen Buddhist doctrines. The control group studied two introductory passages dealing with the historical and biographical nature of Buddhism and Zen Buddhism.

Two days after studying their respective introductory passages, both control and experimental groups restudied their introductory passages and then studied the Buddhism passage. Two days later the experimental and control groups were tested on the Buddhism passage and then studied the comparative Buddhism-Zen Buddhism organizer and the control introduction, respectively. Again, after two days the groups restudied their respective introductory passages and then studied the Zen Buddhism passage. Both groups were tested on the Zen Buddhism passage after one week.

Results indicated that the previously learned background knowledge has a significant facilitating effect on the learning and retention of the Buddhism material when verbal ability was statistically controlled. Similarly, knowledge of the Buddhism passage significantly facilitated the learning and retention of the Zen Buddhism passage. The organizer treatment facilitated the learning and retention of the Buddhism passage; however, the organizer treatment for the Zen Buddhism passage did not significantly facilitate learning and retention. Finally, although there was a significant difference among the verbal ability categories, a noticeable but not statistically significant interaction between the organizer and verbal ability was observed for the Buddhism criterion scores.

Finally, Fitzgerald and Ausubel (1963) hypothesized that learners who had a negative attitudinal bias toward a controversial topic lacked clear and stable subsumers in cognitive structure regarding the topic. More specifically, it was hypothesized that (a) there is a positive relationship between the clarity and stability of cognitive structure and the learning and retention of controversial material, and (b) the introduction of a relevant comparative organizer would facilitate the learning and retention of controversial material.

Two hundred and sixty-four high school juniors enrolled in 16 sections of an American history course were stratified according to attitude, prior knowledge of the subject matter, sex, and class section and randomly assigned to one of four treatment groups. The treatment groups consisted of two experimental groups and two control groups. Each experimental group studied a 450 word comparative introductory passage one day before studying a 2,900 word Southern interpretation of the causes of the Civil War. The comparative introductory material pointed out the principal similarities and differences between the Northern and Southern viewpoints regarding the causes of the Civil War. A multiple choice knowledge test was administered to one experimental group directly after it studied the longer learning passage, and the other group took the test one week later.

The procedure for the two control groups was the same as that of the experimental groups, with the exception that the introductory material discussed the possibility of different historical interpretations of the Civil War.

Results indicated that the comparative introductory treatment had a statistically significant effect in facilitating learning and retention of controversial material. These effects were also noted when verbal reasoning ability was statistically controlled. The benefits derived from the comparative introductory treatment were especially associated with the retention scores rather than on the immediate test of knowledge. Finally, it was suggested that prior relevant knowledge, as measured by a pretest, facilitated learning and retention. The data indicated that those persons who were in the upper subgroup with regard to prior knowledge regarding the topic appeared to benefit most from the comparative treatment.

In a more recent study, Scandura and Wells (1967) utilized more concrete introductory materials than the highly abstract verbal organizers that Ausubel had used. They hypothesized that the learning of abstract mathematical content would be more enhanced by concrete model introductions (mathematical games) than by historical introductions.

Subjects were predominantly college women (100 women and four men) who were elementary education majors. They were randomly assigned to one of four treatment groups. The treatment groups consisted of two levels of introductory experience (history or concrete organizer) within two levels of subject matter (group or topology).

Prior to studying 1,000 word passages dealing with either abstract mathematical groups or combinatorial topology, the subjects were provided with an appropriate historical or a concrete model introduction. The historical introductions were about 1,000 words in length and dealt with men who had a significant role in the early development of each subject matter. The group introduction consisted of a mathematical game, called "followed-by," in which the structure of a mathematical group was presented in language familiar to the subjects. The topology introduction consisted of a game, called "play like," in which topological facts about lines, curves, arcs, and networks were presented in a simple and understandable manner.

An analysis of both knowledge and efficiency scores indicated a significant difference between the history and concrete introductions. The concrete introductions were generally more facilitating, especially with the topology material. Significant differences were also observed between the topology and group subject matter treatments. It was reasoned that the lower effectiveness of the concrete introductions on learning the group material may have been due to the fact that the subjects were more familiar with the group material than the topology material.

A study by Grotelueschen (1967) attempted to ascertain the effects on adult learning of experimentally manipulating the structure and sequence of learning material.

A sample of 96 adults who were unfamiliar with the number base learning topic and who ranged in age from 23 through 53 were classified according to a 4 x 3 x 4 x 2 factorial design. Subjects were randomly assigned to four introductory material and three learning task conditions within four categories of intelligence and two categories of sex, respectively. Subjects attended an individual session where a set of the introductory materials (history of measurement, base ten, base seven, or principles of number bases) was administered to them in the form of a programed learning booklet. After completing the introductory material, subjects prelearned the four basic symbols utilized in the subsequent base four learning task and were individually presented the learning task condition (random, partial, or complete) in paired associate form by a randomly assigned session administrator. Upon responding correctly to a criterion of two perfect trials on the paired associate task, the subjects were administered a posttest. Measures of the trials and errors to criterion were also obtained.

The data were analyzed by use of the ANOVA and the *L* test. The results suggested no statistical differences among the introductory material conditions. This nonsignificant finding was primarily attributed to the abstractness of the learning topic for adults with no prior background information. The findings did suggest, however, that the facilitative effect of the introductory material on the subsequent base four number task appeared to be relatively greater for adults with superior intelligence. It was also found that the presentation of a learning task in a completely sequential ordering resulted in a more rapid acquisition of the learning task than when the task was partially or randomly presented. Furthermore, evidence suggested that the effect of the completely sequenced learning task appeared to be especially beneficial for adults with relatively low intellectual abilities. Inconclusive evidence suggested that partially sequenced learning tasks had a greater facilitative effect on the transfer value of the learning task. No evidence was found to suggest that the effects of differentially structured introductory materials would be less facilitative for a completely sequenced learning task than a learning task presented in a completely unsequenced manner. There were, however, some tentative findings which suggested that the relative effect of a completely sequenced learning task would become greater as the introductory material became less structured. Reliable differences among the intelligence categories and between sexes were observed among the criterion measures in the analyses. The findings indicated a positive relationship between intelligence and performance on the learning task. Also, the data suggested that men performed consistently better than women, especially when application of the learned number base principles was required.

These findings by Grotelueschen (1967) were supported by two earlier related experiments reported by Grotelueschen and Sjogren (1968) on the effects of differentially structured introductory materials and learning tasks on learning and transfer. These two experiments were conducted independently, but both were designed to test the prediction that performance on a concept attainment task is positively related to the degree to which (a) introductory material studied prior to the learning task is structured, and (b) the learning task is sequentially arranged. The experiments used similar materials, procedures, and criterion measures as the study by Grotelueschen (1967), but the subjects in both experiments were adults of superior intelligence.

The results of both experiments supported the hypothesis that introductory materials can facilitate the learning and transfer of a number base concept. This was indicated by the acquisition of learning as measured by errors and trials to criterion, and transfer of learning as measured by the total and transfer posttests. The results also indicated that partially sequenced learning tasks appeared to have a greater facilitative effect on transfer than material which was completely or randomly sequenced.

EXPERIMENTAL STUDIES

In the Introduction of this report, the theory and relevant empirical literature were presented as a background for the specific problems of the following experimental studies. In this section, the specific rational, procedures, and results for each of the three interrelated studies are described.

Experiment I

Purpose

The general purpose of this experiment was to ascertain the effects of prior relevant subject matter knowledge, differentially structured introductory learning materials, and differentially sequenced learning tasks on learning acquisition and transfer.

Rationale

Ausubel (1963b, 1965) has theorized that meaningful learning is facilitated by two variables which enhance the learner's cognitive structure (i.e., his existing organized body of knowledge regarding a learning topic). One variable is the *structure* of the subject matter itself. This refers to those substantive aspects of the subject matter that have the greatest generalizability, inclusiveness, and relatability within that subject matter area. The second variable is the manner in which the subject matter is presented, arranged, and ordered. This emphasis on *sequencing* is referred to by Ausubel as the programmatic aspect of presenting material.

The recent findings reported by Grotelueschen (1967) and Grotelueschen and Sjogren (1968) provide evidence which supports the assumption made by Ausubel that meaningful learning is facilitated by the manipulation of the structure and sequence of a subject matter. These findings indicate that the facilitative effect of differentially structured materials occurred primarily with adults of superior ability who had no background knowledge regarding the learning topic. The facilitative effects were observed not only on learning acquisition, as measured by trials and errors to criterion (Grotelueschen, 1967; Grotelueschen and Sjogren, 1968), but also on transfer, as measured by a completion-type posttest (Grotelueschen and Sjogren, 1968).

Findings also indicated that the presentation of a learning task which was completely sequenced resulted in a more rapid acquisition of the learning task than when the task was partially or randomly presented (Grotelueschen, 1967; Grotelueschen and Sjogren, 1968). It was found, however, that partially sequenced learning tasks appeared to have a greater facilitative effect on transfer than material which was completely or randomly sequenced (Grotelueschen and Sjogren, 1968). Furthermore, the evidence indicated that the effect of the completely sequenced learning task appeared to be especially beneficial for adults with relatively low ability and little or no relevant background knowledge (Grotelueschen, 1967).

Although it was hypothesized by Grotelueschen (1967) that the effects of differentially structured introductory materials would be less facilitative for a completely sequenced learning task than a completely unsequenced task, there was some tentative evidence which appeared to suggest that the relative effect of a completely sequenced task would become greater as the introductory material became less structured. That is, the effect of ordering elements in a learning task is dependent upon the extent of relevant substantive information given prior to the task. It seems reasonable to assume that the greater the extent to which the introductory learning material is structured (i.e., contains substantive information), the less facilitative effect there would be in the sequential arrangement of the learning task. Or, the less relevant substantive information available to the learner prior to learning a task, the more the learner is dependent upon the organization of the learning task itself.

The previously cited findings regarding the facilitative effects on learning and transfer of the structure and sequence of a learning topic seem to warrant a more conclusive test of (a) the effects of the introductory material and learning task treatments on both learning acquisition and transfer, (b) the interaction between the experimentally manipulated structure and sequence variables, and (c) the effect of prior subject matter background and its interaction with both structure and sequence variables.

The findings also indicated that the effect on learning acquisition is positively related to the degree to which the learning task is sequentially arranged. However, when the learning task was partially sequenced there appeared to be a greater facilitative effect on an immediate test of transfer than when material was completely or randomly sequenced. It was expected that the learning task treatments might result in the use of different strategies of learning which would affect transfer. The partially sequenced treatment was expected to influence the subjects to select a principle which would facilitate the learning of the material. This expectation was based on the rationale that if the stimulus material of the learning task was partially ordered to suggest the existence of a principle, then the subjects might use strategies to learn the principle. If, however, the stimulus material was completely ordered so that a maximum amount of information was being presented, then it might be expected that the subjects would use a rote strategy instead of a principle learning strategy. There is, however, the possibility that the ordered presentation might also induce the subject to seek a principle, but to a lesser extent than the partial treatment. Finally, it would be expected that a rote strategy would be used with randomly presented material, because the subject would be faced with the task of testing too many strategies, that is, if he could extract enough information from the task to test any strategies. Therefore, if the observed effects were noted on an immediate measure of recall and transfer, and if the assumption regarding the learning of principles is valid, then similar results would also be expected on a delayed measure of transfer. This testing of the optimal ordering of words and symbols to guide the learning of principles and subsequent transfer has been raised by Gagne (1966, p. 92).

In addition to ascertaining the effects of the structure and sequence of learning material, this experiment was designed to ascertain the effect of prior subject matter background and its interaction with both structure and sequence variables. Evidence regarding the facilitative effect of relevant background knowledge on the subsequent learning and retention of unfamiliar material indicated that learners with more background knowledge obtained significantly higher scores on tests covering the related learning material (Ausubel and Fitzgerald, 1961b; Ausubel and Fitzgerald, 1962; Ausubel and Youssef, 1963; Fitzgerald and Ausubel, 1963). This dependence of learning and retention on related subject matter knowledge was also supported by data regarding the facilitative effects of initial learning on sequentially presented material (Ausubel and Fitzgerald, 1962) and on the learning of parallel material (Ausubel and Youssef, 1963).

The findings of Ausubel (1960) and Scandura and Wells (1967) seem to suggest that the facilitative effect of introductions may be lessened by the learner's prior relevant knowledge. It might be hypothesized, therefore, that if different levels of relevant background knowledge were controlled in an experiment with adults of high ability for whom introductory materials were facilitative, then the effects of the introductory materials would be less beneficial for learners with a high degree of background knowledge. This does not imply, however, that significant main effects are necessary for interactions to occur. Similarly, the effect of sequential arrangement of a learning task on learning acquisition and transfer would be lessened as relevant background knowledge increased. That is, the effects of completely sequenced material on learning acquisition and the effects of partially sequenced material on transfer would be less beneficial for learners with substantial background knowledge.

Hypotheses

The following hypotheses were tested in this experiment. Where applicable, specific predictions are made for each of the proposed criteria.

1. There is a significant difference among the differentially structured introductory learning materials. It is expected that the more generalizable and inclusive the introductory material, the greater effect there will be on learning acquisition and transfer.

2. There is a significant difference among the differentially sequenced learning tasks. It is expected that the greater the extent to which the learning task is sequentially arranged, the greater will be the effect on learning acquisition. However, it is expected that on the transfer criterion the order of the treatment means will be partial > complete > random.

3. There is a significant difference among the subject matter background categories. It is expected that persons with more prior subject matter background will perform better on the criterion measures than will those with less background knowledge.

4. There is a significant interaction among the differentially structured introductory materials and the differentially sequenced learning tasks. It is expected that the relative effect of a completely sequenced learning task would become greater as the introductory material becomes less structured, especially in criteria of learning acquisition.

5. There is a significant interaction among the differentially structured introductory materials and the levels of prior subject matter background. It is expected that the effectiveness of the introductory material will decrease as the learner's relevant subject matter background increases.

6. There is a significant interaction among the differentially sequenced learning tasks and the levels of prior subject matter background. It is expected that the effectiveness of the completely sequenced learning task will decrease on a measure of learning acquisition as the learner's relevant prior subject matter background increases. It would also be expected that the effectiveness of the partially sequenced task on a transfer test would decrease with increased prior subject matter knowledge.

Method

Subjects. The subjects for this experiment consisted of 91 paid young adults who resided in a midwestern city. These subjects had scored within a desired range on a Number Base Systems Pretest (Appendix A), had completed at least two years of college, and had an average estimated WAIS full scale IQ score equivalence of 112 derived from their performance on the Quick Word Test (Grotelueschen and McQuarrie, 1970).

Design. The experimental design was a fixed effects 4 x 4 x 2 factorial design. Within two levels of prior knowledge of number bases, subjects were assigned at random to one of four sets of introductory materials and one of four learning tasks.

Materials. The four sets of introductory instructional materials used in this study were linear self-instructional programs used previously by Grotelueschen (1967). All programs consisted of 95 frames. The first taught details of the *base ten* numeration system. The second taught the *base seven* system and included transformations to and from base ten. All instructions regarding base seven were given only in terms of that base, no attempt being made to identify any general principles. The third program taught the *principles* on which different numeration systems may be established and the principles of conversion to and from base ten. Specific examples of all the principles were included but were restricted to numeration systems with bases less than ten. No examples were chosen from base four, since the learning task involved that numeration system. The fourth program, the *control*, taught the history of measurement.

The learning task presented the base four representation of the base ten numbers zero through twelve. They were projected from 35mm slides which presented pairs such as: seven 13. In one treatment (*sequenced*) the numbers were presented sequentially from zero through twelve. In a second treatment (*partial*), the first seven slides were zero through five and then eight (0, 1, 2, 3, 10, 11, 20), with the remaining six slides in random order. In a third treatment (*random*), the thirteen slides were randomly arranged. Subjects in the fourth treatment (*control*) were allowed to study privately from unrelated materials they had been advised to bring with them.

Levels of the third factor in the design, prior knowledge, were established on the basis of the Number Base Systems Pretest. The twenty items on this test were all five-option multiple choice, requiring subjects to identify face and place values of numerals in numeral sets in various bases, and to transform numbers in bases less than ten to base ten. Subjects were classified as *high* or *low* on the pretest according to whether their score was greater than or less than 10. Subjects with scores of 10 were not used in the study. Neither were persons included who had scores of 19 or 20.

Dependent Variables. Four dependent variables were used in this study. Two were intended to assess the effectiveness of the instructional materials. One of these, the *posttest*, contained ten items repeated from the pretest. The other, the *computation test*, required addition, subtraction, multiplication and division of numbers in bases other than ten, with answers to be given both in the original base and base ten. There were eight of these items, each with two answers required. Appendix B provides the instrument (Number Base Systems Posttest) in which these two measures are contained. Part A is the *posttest*. Part B is the applicational *computation test*.

The remaining two dependent variables were intended to assess performance on the learning task. One, the *base four test*, required the base four representation of eight base ten numbers between zero and twelve. The second, the *base four transfer test*, required the base four representation of eight base ten numbers greater than twelve but less than one hundred, that is numbers outside the range presented in the learning task. Appendix C contains the instrument (Number Base Achievement Test) in which these subtests are contained.

Procedure. The subjects selected for the experiment on the basis of pretest scores were invited to attend one of two two-hour sessions. Subjects had been randomly assigned, within levels of pretest score, to one of the 16 combinations of instructional material and learning task. The subjects worked at their own pace through the instructional materials, with the slowest persons taking about 50 minutes. Subjects who finished quickly were able to read or study from materials they had brought with them.

When all had finished, the subjects in the three experimental learning task groups went to different rooms where the learning task was presented. These presentations consisted of successive learning and test trials, with the cues being presented in random order on each test trial. Nine trials were presented to all groups.

Subjects then returned to the main experimental room where the criterion measures were presented. Subjects were paid upon completion of the entire task.

Results and Discussion

Instructional Materials. Mean performances on all four criterion measures, for subjects receiving each set of instructional materials, are shown in Table 1. Differences among the groups were significant on the posttest, $F(3,59) = 15.5$, $p < .001$, and the computation test, $F(3,59) = 3.3$, $p < .03$. The order of the group means on both of these variables was base seven > principles > base ten > control. *Post hoc* comparisons among the means using the Tukey HSD test (Kirk, 1968, pp. 88-90) revealed that, for the posttest, the control group performance was significantly lower than that for the other groups ($p < .01$)

whereas, for the computation test, none of the differences between means reached conventional levels of significance.

Table 1

Mean Proportion of Items Correct on Criterion Measures as a Function of Instructional Materials

Instructional Material	Posttest	Computation Test	Base Four Test	Base Four Transfer Test
Base ten	.76	.43	.88	.48
Base seven	.91	.49	.88	.71
Principles	.84	.48	.83	.50
Control	.54	.28	.71	.02

These main effects should be interpreted cautiously, however, since there were significant interactions between this factor and others for both of these dependent variables.

On the tests designed more specifically to assess the learning task, there were no significant differences due to introductory materials in the case of the base four test, $F(3,59) = 1.3$, but there were for the base four transfer test, $F(3,59) = 6.9$, $p < .001$. For the latter variable, *post hoc* comparisons revealed the performance of the control group to have been significantly lower than that of the base seven group ($p < .01$) and that of the principles group ($p < .05$).

Learning Task. Mean performances, on all four dependent variables, for subjects receiving each learning task, are shown in Table 2.

Table 2

Mean Proportion of Items Correct on Criterion Measures as a Function of Learning Tasks

Learning Task	Posttest	Computation Test	Base Four Test	Base Four Transfer Test
Sequenced	.76	.40	.85	.45
Partial	.78	.43	.84	.43
Random	.72	.36	.81	.49
Control	.77	.49	.80	.53

Differences among the means were not significant on any of the variables.

Earlier research (Grotelueschen and Sjogren, 1968) had indicated that, while there was faster acquisition with a fully sequenced learning task, there was greater facilitative effect on transfer with a partially sequenced task. In the present study there were no significant differences among learning sequences on either the base four test or the base four transfer test. The learning task in the present study, which used the usual Arabic numerals, was much simpler than that used by Grotelueschen and Sjogren (1968).

Pretest Level. As was expected, the main effect for pretest level was highly significant on each of the four variables ($p < .001$). This main effect, however, is of little consequence for the present study. This factor, level of prior knowledge, was included for the purpose of studying its interaction with the experimental treatments.

Instructional Materials X Learning Tasks. The instructional materials X learning task interaction was not significant for either of the criterion measures intended specifically to assess the effectiveness of the learning task. For the base four test the result was $F(9,59) = 1.6$ and for the base four transfer test it was $F(9,59) = 0.8$.

It might have been expected that any advantages of the partially sequenced learning task on transfer would have been lessened as the introductory materials became more structured. That is, structured introductory materials, such as the principles program, should have provided sufficient relevant substantive information to the learner prior to the learning task for the relative advantages of the differentially sequenced learning tasks to be minimized. The present results indicate, however, that there were no such relative advantages of the differentially structured materials.

On the more general tests of number base knowledge, the instructional materials by learning task interaction was not significant in the case of the posttest, $F(9,59) = 1.58$, but it was for the computation test, $F(9,59) = 2.2$, $p < .04$. This interaction is shown in Figure 1.

For subjects in the sequenced learning task, the control group on the instructional materials was significantly inferior to all three instructional treatment groups ($p < .05$) which did not differ among themselves. The absence of prior instruction in number bases, in the case of the control group, presumably resulted in a rote strategy being employed during the sequenced learning task from which there was no transfer to performance on a test of knowledge of number bases.

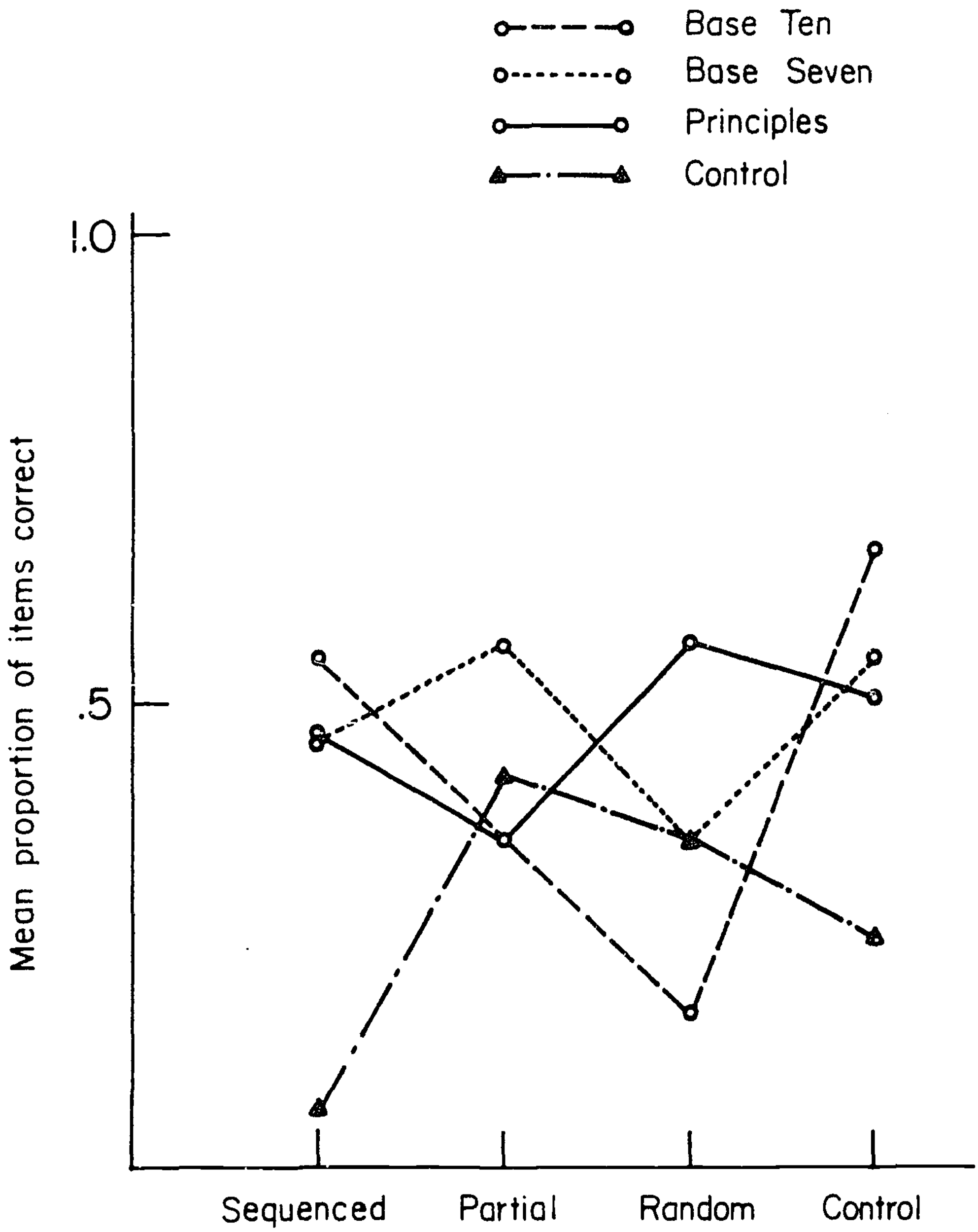

FIG. 1. Mean performance on computation test as a function of instructional materials and learning task.

On the partially sequenced learning task, for which a non-rote strategy was more likely to be used, there were no significant differential effects due to prior instructional materials.

For the randomly ordered learning task, on which it would be difficult for subjects to formulate a non-rote learning strategy, the performance of those who received instruction in the principles of number bases was best. Their performance was significantly better than that of subjects who received the base ten program ($p < .05$).

For subjects in the control group on the learning task, the performance of those in the control group for instructional materials was lowest, though significantly lower than only the base 10 group ($p < .05$).

There is evidence from previous research that subjects less likely to use a rote strategy on the learning task will perform better on transfer tasks, and from the present results that the differential effect of differentially structured prior materials will be lessened when the learning task itself is less likely to generate rote learning strategies.

Instructional Materials X Pretest Level. The instructional materials by pretest level interaction was significant only for the posttest, $F(3,59) = 4.7$, $p < .01$. It was not significant for the computation test, $F(3,59) = 0.1$, the base four test, $F(3,59) = 1.5$, or the base four transfer test, $F(3,59) = 0.1$. The interaction for the posttest is shown in Figure 2.

For subjects high on pretest level there were no significant differences due to instructional materials. There is the possibility that this may have been due to a ceiling effect on the test, however. For subjects who were low on the pretest, that is with little knowledge of the materials taught in the instructional materials, the performance of those receiving the control (history of measurement) program was significantly lower than those receiving any one of the programs dealing explicitly with number bases ($p < .01$). Among the number base programs, the base seven program was significantly better than the base ten program ($p < .05$) with the principles program in between.

It was expected that the principles program would be superior overall to the other programs, but that its superiority would be less marked for subjects with greater prior knowledge of number bases. On the posttest, however, the overall result was that, while all number base programs were significantly superior to the control program, there were no significant differences among them. Among subjects with less prior knowledge, the base seven program was the most effective. The principles program appears to have been too abstract for subjects to relate the information to any prior relevant information.

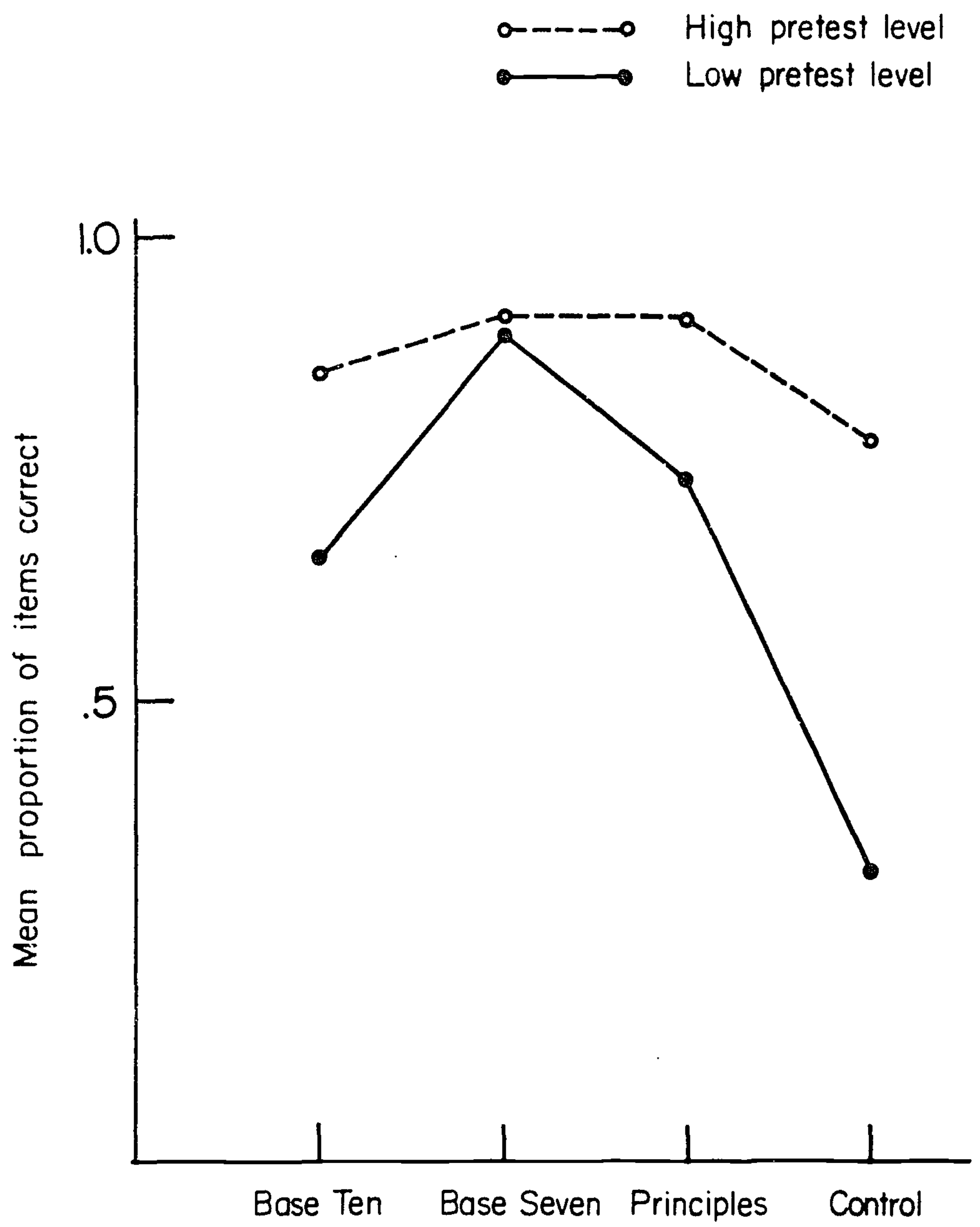

FIG. 2. Mean performance on posttest as a function of instructional materials and pretest level.

Learning Task X Pretest Level. The learning task by pretest level interaction was significant only for the computation test, $F(3,59) = 3.0$, $p < .04$. It was not significant for the base four test, $F(3,59) = 0.2$, the base four transfer test, $F(3,59) = 1.5$, or the posttest, $F(3,59) = 1.1$. The significant interaction on the computation test is shown in Figure 3.

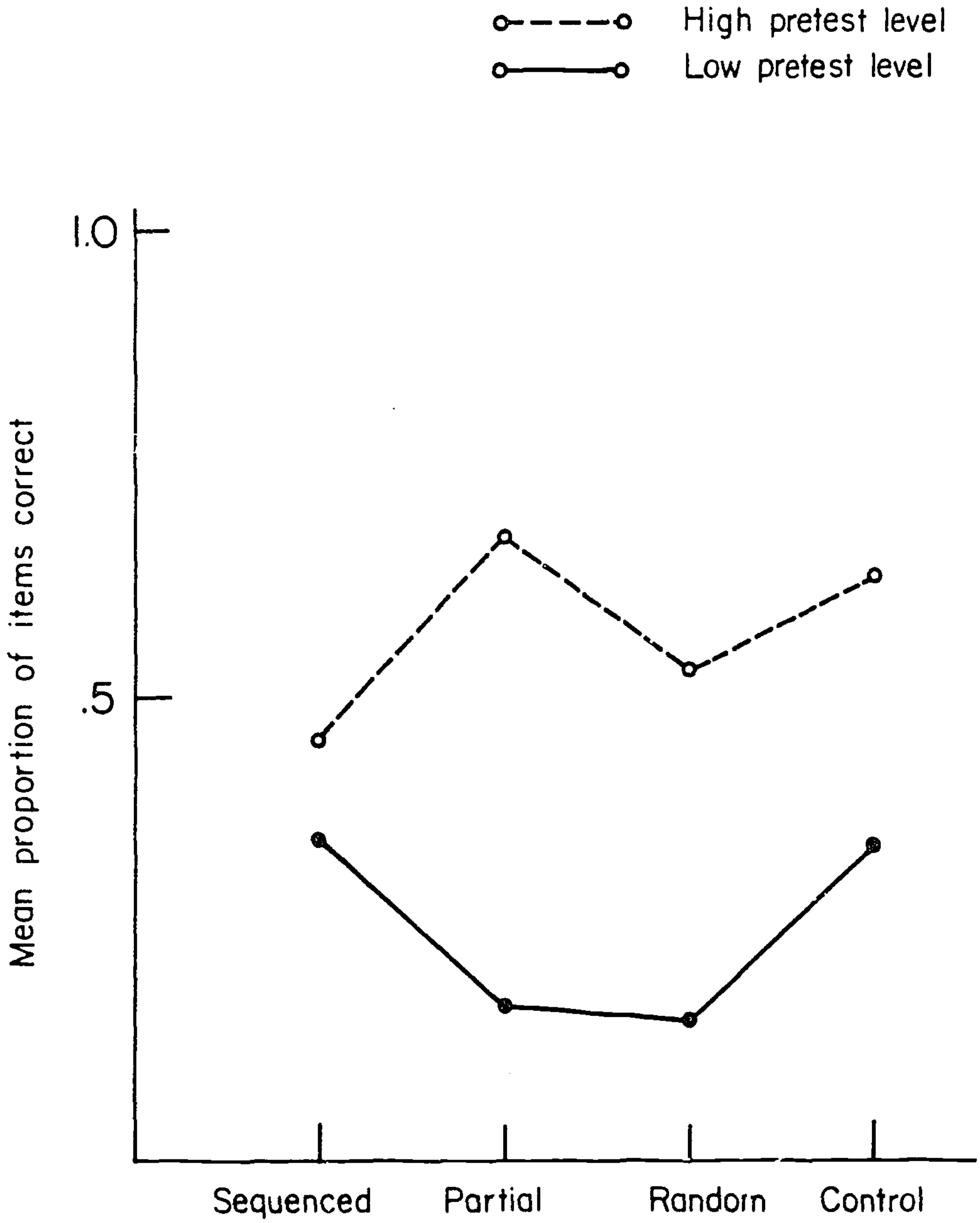

FIG. 3. Mean performance on computation test as a function of learning task and pretest level.

The dependent variable on which this significant interaction occurred was not intended as a measure of success on the learning task itself, which dealt only with the base four numeration system. *Post hoc* comparisons among the means, within levels of pretest scores, however, revealed that there were no significant differences among the learning tasks at either high or low pretest level.

Conclusions

In this study differentially structured instructional materials were given to subjects prior to differentially sequenced learning tasks.

The results indicated that transfer to the tasks, measured by a general test of computational skills with changes in base, occurred most readily following a partially sequenced learning task on which a base related non-rote learning strategy could be most readily developed. Prior instructional materials dealing with general principles of number bases were differentially effective when a fully randomly sequenced learning was employed on which it was difficult to develop a base related non-rote learning strategy. That is, the provision of relevant substantive information to the learner prior to the learning task, is differentially effective, with the facilitation being greatest when it is more likely that, without the prior information, the learner will use rote strategies.

A similar differential facilitation was noted with subjects differing in prior knowledge. The facilitation of structured introductory materials was greatest for subjects with little prior knowledge.

Experiment II

Purpose

The general purpose of this experiment was to ascertain the extent to which self-regard and learning performance are influenced by the type and extent of feedback received during stages of a mathematical learning activity. Differential performance by men and women were also ascertained.

Rationale

Considerable incidental evidence (Billings, 1934; Guetzkow, 1951; Maier, 1945) has accumulated which indicates that men perform better than women in solving certain kinds of problems. More recent evidence (Sweeney, 1953) suggests that these differences occur even when intellectual variables are controlled. As a result, a number of studies

(Carey, 1958; Milton, 1957; Nakamura, 1958) have sought to ascertain the relation between sex differences in problem solving and various nonintellectual variables. Although the findings from these studies are by no means conclusive, they do provide substantial evidence to indicate that nonintellectual variables (e.g., attitude, anxiety) do contribute to sex differences in problem solving performance.

Grotelueschen (1967) also found significant differences between adult men and women with the effects of intelligence, age, and prior subject matter knowledge controlled. Men performed consistently better than women, especially when application of the abstract principles of a number base was required. These findings, too, suggest that the observed sex differences could be accounted for by differences in nonintellectual variables.

Researchers generally agree that sex differences are attributable in part to social-cultural factors. Therefore, if social-cultural expectations of, and reactions to, an individual have a general influence on his problem solving ability, then it might be reasoned that the specific reactions of "significant others" would also have an influence on the individual's learning ability. The assumption that social reaction, or more specifically the response of significant others, is functionally related to an individual's concept of self has been theorized by Mead (1934) and Sullivan (1953). Experimental evidence to support this assumption has been gathered by Videbeck (1960), Maehr, Mensing, and Nafzger (1962), Haas and Maehr (1965), and Ludwig and Maehr (1967). These studies have also provided evidence to support the assumption that the concept of self has a predictable effect on behavior.

The studies by Videbeck and by Maehr and his associates were concerned with aspects of human activity in which subjects were assumed to have attitudes of self-regard.[2] Prior to performing certain activities in a selected area of behavior, attitudes of the subject's self-regard were measured by a rating scale. Upon completion of the assigned activity an expert arbitrarily praised (approval) or criticized (disapproval) each subject's behavior. The self-rating scale was readministered after the approval-disapproval treatment.

The findings of Videbeck (1960) indicated a significant difference between before and after self-ratings in the predicted direction for the disapproval treatment. The approval treatment was also in

[2] Videbeck used college undergraduates as subjects and focused on attitudes toward self in the area of oral communication (i.e., reading poetry). Maehr and his associates focused on the physical self concepts of adolescent boys.

the predicted direction, but the difference was not statistically significant. These observed findings not only were noted on the attributes directly referred to by the expert (criticized scale), but also on related attributes. Maehr, Mensing, and Nafzger (1962) replicated the findings of Videbeck, with one exception. They found that the approval treatment also resulted in a significant amount of change in the predicted direction. Haas and Maehr (1965) extended the earlier studies by attempting to ascertain the durability of experimentally induced changes in self-ratings and the effect of extent of influence on such changes. The results indicated that the effects for both approval and disapproval treatments on the criticized scale were still significant six weeks after the treatments were administered. Also, the administration of two approval treatments resulted in greater and longer lasting changes in self-ratings than the administration of one treatment. Most recently, Ludwig and Maehr (1967) also found the approval treatment to increase the subjects' self-ratings and the disapproval treatment to decrease self-ratings. Secondly, they found that the effects appeared to spread to areas of self-regard not directly approved or disapproved. Finally, approval was followed by increased preference for physical activities directly related to the treatment, whereas disapproval resulted in a decreased preference for these activities.

The previously cited findings suggest that if adult learners have attitudes regarding their ability to learn a specific task, and if these attitudes are influenced by significant others, then it might be predicted that the individual's self-regard concerning the activity and his actual learning performance in that activity might not only be influenced by his sex, but also by the different types and extent of feedback which he receives during several stages of a learning activity.

Hypotheses

The following hypotheses were tested in this experiment.

1. There is a significant difference between the types of positive-negative feedback received by the subjects. It is expected that positive feedback will be associated with increased self-ratings and learning performance.

2. There is a significant difference between the sex categories. It is expected that men will perform better on the self concept and learning criteria.

3. There is a significant difference among the extent of feedback treatments. Increased extent of positive feedback will be positively associated with self-ratings and learning performance, whereas

increased extent of negative feedback will be negatively associated with self-ratings and performance in learning.

4. There is a significant difference between the categories of prior knowledge related to the learning activity as measured by the self-ratings and learning performance criteria.

5. There is a significant ordinal interaction between the types of positive-negative treatments and the sex categories on the criterion measures. Women are expected to be affected more by the treatments than men.

Method

Subjects. The subjects for this experiment consisted of 112 paid young adults who were residents of a midwestern state capital. They had an average age of 25 years, had an average of four years of college, and had an average estimated WAIS full scale IQ score equivalence of 113. This score was derived from their performance on the Quick Word Test.

Design. The experimental design was a fixed effects 2 x 2 x 7 factorial design. Within two levels of prior knowledge of number bases and two levels of sex, subjects were assigned at random to one of seven feedback treatment conditions.

Treatments. The first two factors in the design were sex (*male* and *female*) and prior knowledge of number base systems. The two levels of prior knowledge were established on the basis of the subjects' performance on the Number Base Systems Pretest (also used in Experiment I). The twenty items on this test were all five-option multiple choice, requiring subjects to identify face and place values of numerals in numeral sets in various bases, and to transform numbers in bases less than ten to base ten. Subjects with pretest scores above ten were classified as *high*, while subjects with scores of ten or below were classified as *low*.

The third factor in the design was the type-extent feedback treatment. This experimental treatment consisted of seven levels. One level (*Extensive Positive*) provided oral positive feedback from an experimenter to the subject after he had completed each of three sections of learning material. A second level (*Moderate Positive*) provided neutral feedback to the subject ("Please continue to the next part.") after he had completed the first section of the learning material, and positive feedback after he had completed each of the second and third sections. A third level (*Limited Positive*) provided neutral feedback to the subject after he had completed each of the first and second sections of the learning material, and positive feedback only after he had completed the third section. The fourth level (*Control*) provided neutral feedback to the subject after all three sections of learning material. The fifth level (*Limited Negative*) provided neutral feedback to the subject after he had completed each of the first and second learning material sections, and negative feedback after he had completed the third section. The sixth level (*Moderate Negative*) was the same as the Moderate Positive treatment with the exception that the subject received negative feedback instead of positive. The seventh level (*Extensive Negative*) provided negative feedback after each of the three sections of learning material. Table 3 provides a summary of the feedback conditions for the different treatment groups.

The learning material that the subjects studied (and on which they received feedback), and the experimenters who provided the feedback also are described because both were a part of the treatment conditions (albeit a constant part). The learning material consisted of a 150 frame programmed instruction booklet.[3] This linear self-instructional booklet presented information on base ten (frames 1-38), base seven (frames 39-90), and principles of number bases (frames 91-150). Oral feedback for each of the treatment conditions was provided by one of two experimenters after he had inspected a completed section (base ten, base seven, or principles). Experimenters were introduced as professors of mathematics education from a major state university to increase the likelihood that the feedback would have validity for the subjects.

Dependent Variables. Three dependent variables were used in this experiment. The first was the Personal Significance Scale (Appendix D), the second was the Math Opinion Instrument (Appendix E), and the third was the Number Base Systems Posttest (Appendix F). The Personal Significance Scale was designed to measure specific affect associated with the feedback treatment effects. This Scale consisted of three identical parts. Each part assessed the personal significance attached to the feedback given by experimenters on subjects' study performance of the learning material. The Math Opinion Instrument measured the subjects' general self-regard with respect to mathematics. The Number Base Systems Posttest was a revision of the instrument used in Experiment I. It contained four parts. Part A contained five items repeated from the pretest. Parts B and C required the subject to convert base ten numerals into different number bases and vice versa, respectively. (Parts A, B, and C were intended to assess the effectiveness of the instructional material.) Part D required additon, subtraction, multiplication, and division of numbers in bases other than ten, with answers to be given

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[3]Grotelueschen, Arden D. A Look at Number Bases. Urbana, Ill.: Center for Instructional Research and Curriculum Evaluation, University of Illinois. March, 1972.

Table 3

Feedback Conditions for Different Treatment Groups

Treatment	Treatment Occurrence		
	First	Second	Third
Extensive Positive (1)	"You really are doing very well."	"Well, you're still doing very well."	"You've done very well."
Moderate Positive (2)	("Please continue to the next part.")	"You really are doing very well.")	"You've done very well."
Limited Positive (3)	("Please continue to the next part.")	("Please continue to the next part.")	"You've done very well."
Control (4)	("Please continue to the next part.")	("Please continue to the next part.")	("Please continue to the next part.")
Limited Negative (5)	("Please continue to the next part.")	("Please continue to the next part.")	"You've not done as well as we expected."
Moderate Negative (6)	("Please continue to the next part.")	"Considering your background, you really are not doing as well as we would expect."	"You've not done as well as we expected."
Extensive Negative (7)	"Considering your background you really are not doing as well as we would expect."	"Well, you're still not doing as well as we would expect."	"You've not done as well as we expected."

both in the original base and base ten. (Part D tested applicational computation of number bases--information not specifically taught in the instructional material.)

Procedure. Various agencies and groups of a midwestern city were asked to assist with the recruitment of subjects for an adult learning project. A total of approximately 250 young adults each attended one of several hour long sessions which were held over a two week period. At these sessions potential subjects were given information about the project and they completed personal information forms, Number Base Systems Pretests, and Quick Word Tests. Potential subjects were paid for participating in this phase of the study and were told that they would be contacted within a week if they were eligible for participation in the second phase of the project.

In the project's second phase, 112 subjects were invited to attend one of several two hour sessions.[4] The subjects had been randomly assigned to one of the seven feedback treatment groups, within levels of pretest and sex. Subjects studied the instructional booklets at their own pace, but as they completed each section (base ten, base seven, and principles) they were given predetermined feedback on their performance and were administered parts of the Personal Significance Scale. Then the Math Opinion Instrument and the Number Base Systems Postest were administered. Subjects were paid for their participation in the second phase of the study.

Results and Discussion

The following analyses and their discussion relate to the hypotheses of this experiment.

Positive-Negative Feedback. The effects of positive and negative feedback were compared by using contrasts of the means of the dependent variables. This involved comparing the average of the positive feedback means with the average of the negative feedback means. The statistic used was:

$$F = \frac{\text{MS contrast}}{\text{MS within cells}}$$

The difference between positive and negative feedback on the learning performance dependent variable (as measured by the Number Base Systems Posttest) was not statistically significant, $F\ (1,84) = .19$, $p > .05$. The means of the performance for positive, neutral, and negative feedback were 20.10, 21.06, and 20.52, respectively. Thus the type of feedback did not appear to affect the learning performance of the subjects.

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[4]Eight subjects initially invited were replaced because of schedule conflicts.

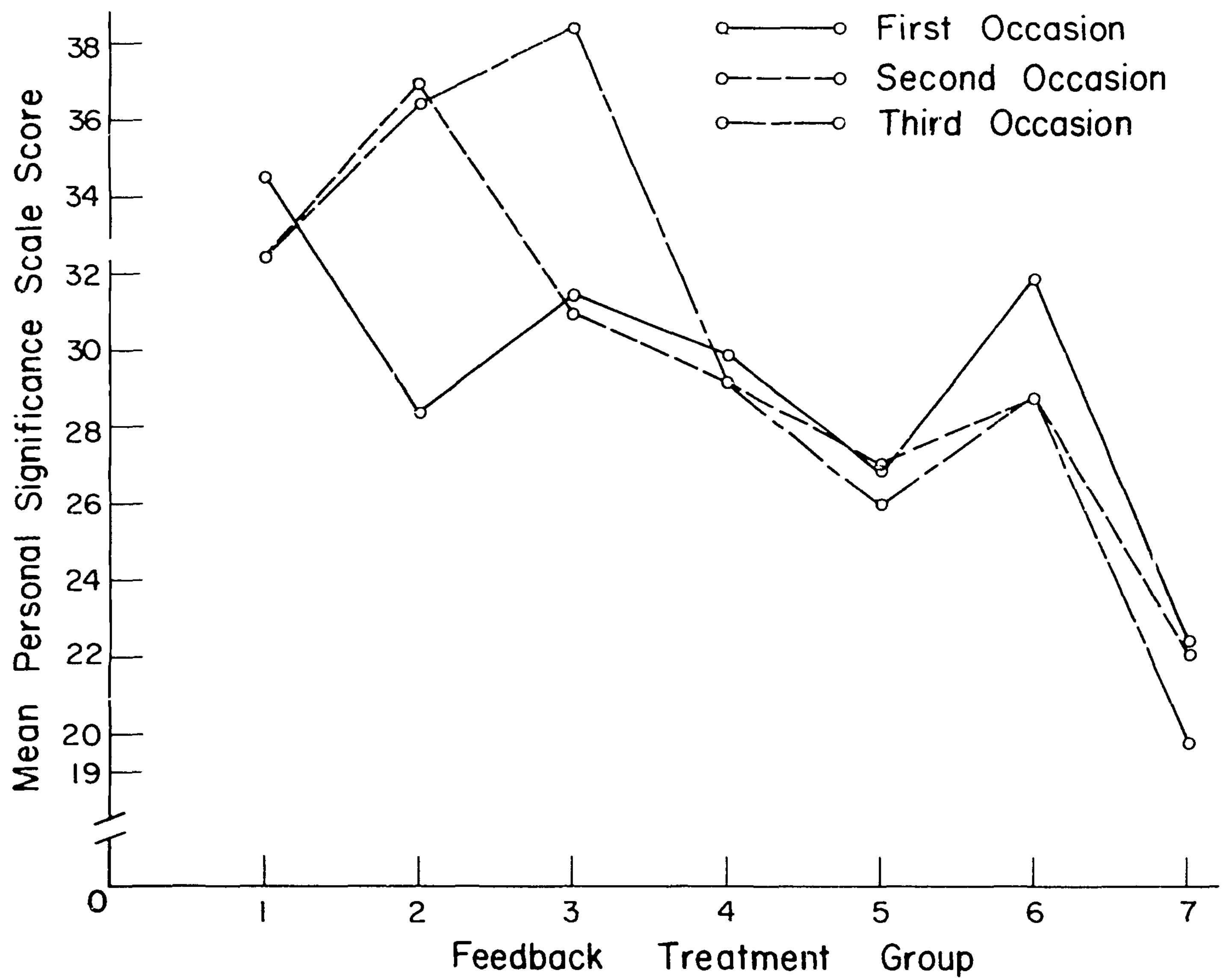

FIG. 4. The effect of occasion by feedback treatment on personal significance scale.

Analysis of each of four subtests of the posttest also revealed no statistically significant results.

On the dependent variable, general self-regard with respect to mathematics (as measured by the Math Opinion Instrument), there was no significant difference between positive and negative feedback, $F(1,84) = .35$, $p > .05$. The means for positive, neutral, and negative feedback were 90.27, 94.87, and 87.35, respectively. Thus the type of feedback did not appear to affect subjects' self-regard with respect to mathematics in general. However, there is the possibility that if the instrument measured self-regard with respect to number base systems (that which was specifically taught), this variable may have been affected by the type of feedback.

That feedback had an immediate specific affect on subjects can be gauged from the results of the administration of the Personal Significance Scale. The instructional booklet was divided into three sections. When a subject had completed a section, feedback was provided, and the Personal Significance Scale, which was designed to measure directly the effect of the treatment, was administered. The results, in terms of means ($n = 16$), are shown graphically in Figure 4 for each of the three occasions of the administration of the Scale. Figure 4 shows that, in general, positive feedback resulted in higher scores than neutral feedback which in turn resulted in higher scores than negative feedback.

For the first occasion there was a statistically significant difference between the mean Personal Significance Scale scores for groups 1 and 7 which received positive and negative feedback respectively, $F(1,84) = 18.81$, $p < .001$. For the second occasion there was a statistically significant difference between the averages of the means of groups 1 and 2 (positive feedback) and groups 6 and 7 (negative feedback), $F(1,84) = 23.32$, $p < .001$. Similarly, for the third occasion there was a statistically significant difference between the averages of the means of the positive treatment groups 1, 2, and 3 and the negative treatment groups 5, 6, and 7, $F(1,84) = 50.34$, $p < .001$.

For each subject, the total of the Personal Significance Scale scores on the three occasions was found. For each treatment group the mean of these total scores were calculated and these are shown in Table 4. There was a statistically significant difference between the positive and negative feedback groups, $F(1,84) = 30.09$, $p < .001$.

It was hypothesized that positive feedback would be associated with increased self-rating. Figure 5 shows, for each of the seven treatment groups, the effect of feedback treatment over the three occasions. The circled points indicate the effect of the first application of either positive or negative feedback. As hypothesized, for treatments 2 and 3, application of positive feedback resulted in substantial

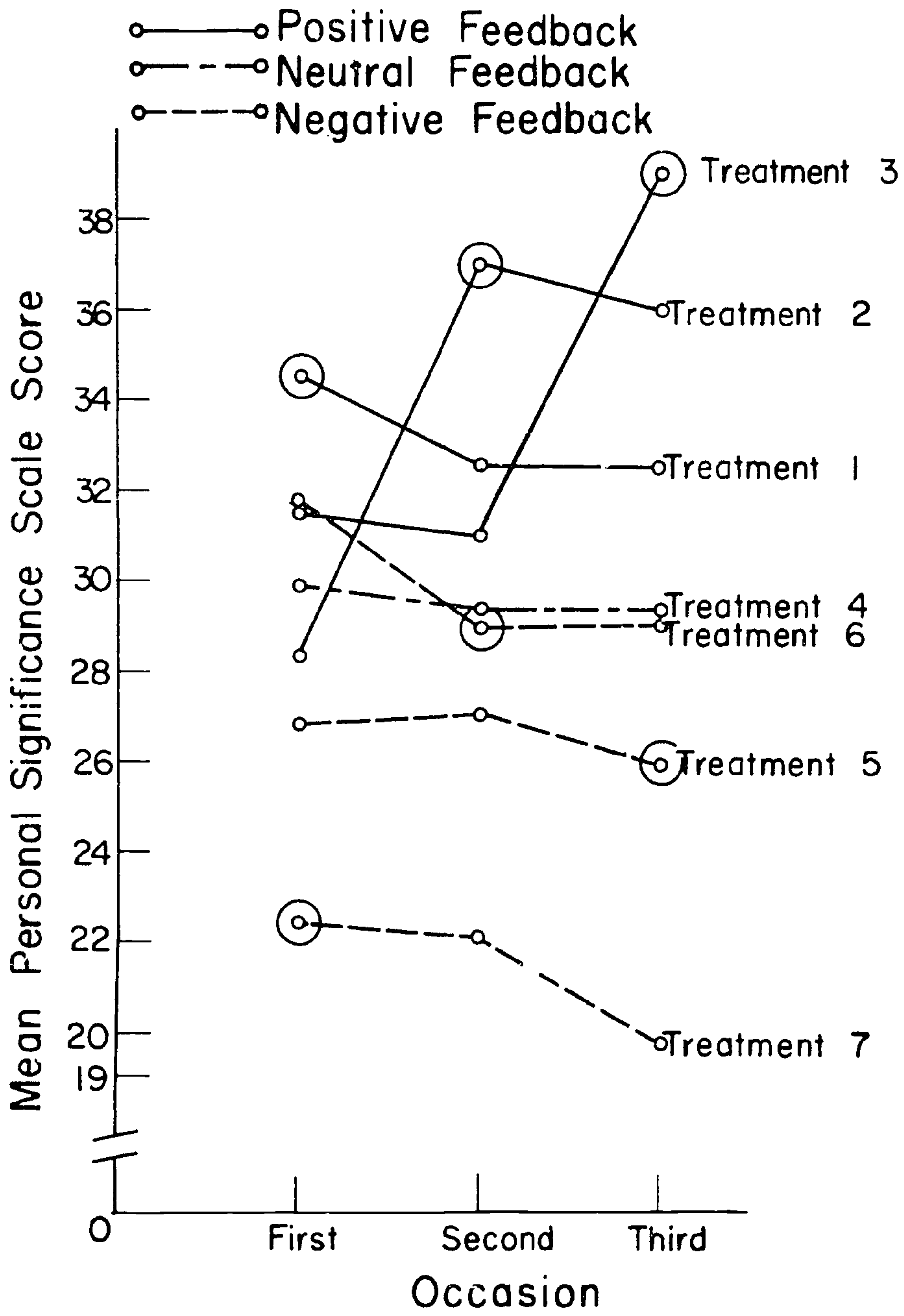

FIG. 5. Treatment variation over occasion on personal significance scale. (Circled points indicate first application of positive or negative feedback.)

Table 4

Mean Personal Significance Scale Scores for Each Occasion and for Each Treatment Group

	Treatment Group Number						
Occasion	1	2	3	4	5	6	7
First	+ 34.5	* 28.4	* 31.5	* 29.8	* 26.8	* 31.8	- 22.4
Second	+ 32.5	+ 37.0	* 31.0	* 29.2	* 27.1	- 28.9	- 22.2
Third	+ 32.5	+ 36.5	+ 38.4	* 29.2	- 26.1	- 29.1	- 19.7
Total	+++ 99.5	*++ 101.9	**+ 100.9	*** 88.3	**- 80.0	*-- 89.8	--- 64.4

Note.--Within each treatment group the first administered positive (+) or negative(-) feedback mean score is underlined. An asterisk (*) represents neutral treatments.

increase in the mean Personal Significance Scale score. However, while there was a corresponding fall for groups 5 and 6 with the application of negative feedback, these falls were by no means as large as the positive rises.

The effect of the change in feedback was tested for significance by using a contrast of the means on the three occasions for each of treatments 2, 3, 5, and 6. The statistic used was:

$$F = \frac{\text{MS contrast}}{\text{MS residual}}$$

For treatment group 2, the mean on the first occasion (neutral feedback) was found to be significantly different from the average of the means on the second and third occasions (positive feedback), $F(1,30) = 31.04$, $p < .001$. For group 3, the average of the means on the first and second occasions (neutral feedback) was significantly different from the mean on the third occasion (positive feedback), $F(1,30) = 24.13$, $p < .001$. In the case of group 5, the average of the means for the first and second occasions (neutral feedback) was not statistically significantly different from the mean on the third occasion (negative feedback), $F(1,30) = 1.02$, $p > .05$. For treatment 6, the mean on the first occasion (neutral feedback) was not significantly different from the average of the negative feedback means on the second and third occasions, $F(1,30) = 1.72$, $p > .05$. Thus it would appear that positive feedback had a more significant effect than negative feedback in a comparison within occasions.

Figure 5 indicates that the graph for treatment 4 (neutral feedback on all three occasions) is practically a straight line. The means for the first, second, and third occasions were 29.8, 29.2, and 29.2, respectively. These figures are very close to 28 which corresponds to a neutral score on the Personal Significance Scale.

In this experiment, subjects were receiving two types of feedback. Firstly, subjects were receiving feedback from the learning materials which consisted of a 150 frame programmed instruction booklet, the answer to each frame being given on the following page. Secondly, the experimental results given above were concerned with the feedback given by the experimenters who were introduced as professors of mathematics education. This second feedback would obviously compete with or reinforce the feedback received by subjects from the instructional materials.

In summary, the positive-negative treatment results indicate:

1. That positive and negative feedback had significantly different effects on subjects' immediate self-ratings, with groups receiving positive feedback having higher self-ratings than groups receiving negative feedback.

2. That when a group received positive feedback after receiving neutral feedback, there was a statistically significant rise in immediate self-ratings. In contrast, when a group received negative feedback after receiving neutral feedback, there was not a statitically significant fall in immediate self-ratings.

3. That while the type of feedback given by the experimenters did have an immediate effect on self-ratings, the effect on learning performance and self-regard with respect to mathematics in general was not significant. One explanation for this is that the effect of the experimenters' feedback was counteracted by the effect of the feedback from the instructional material. Also, the Math Opinion Instrument measured self-regard with respect to mathematics in general and not with respect to number base systems which was the subject matter of the instructional material.

Extent of Feedback. It was hypothesized that increased extent of positive feedback would be positively associated with self-rating and learning performance, whereas extent of negative feedback would be negatively associated with self-ratings and performance in learning.

The difference among the seven treatment groups on the learning performance dependent variable (as measured by the Number Base Systems Posttest) was not significant, $F(6,84) = .40$, $p > .05$. The means of the learning performance for the seven groups, in order from the most positive feedback to the most negative feedback were 20.7, 20.4, 19.2, 21.1 (neutral), 20.9, 19.6, and 21.0, respectively. Thus the extent of feedback did not appear to affect the learning performance of the subjects. Analysis of each of the four subtests of the posttest also revealed no statistically significant results.

On the dependent variable, general self-regard with respect to mathematics (as measured by the Math Opinion Instrument), there was no statistically significant difference among the seven treatment groups, $F(6,84) = .87$, $p > .05$. The means for the seven groups, in order from the most positive feedback to the most negative feedback, were 86.9, 93.2, 90.6, 94.9 (neutral), 92.0, 78.1, and 91.9, respectively. Thus the extent of feedback did not appear to affect subjects self-regard with respect to mathematics in general.

For the first occasion of the administration of the Personal Significance Scale, there was a statistically significant difference among the seven treatment groups, $F(6,84) = 3.99$, $p < .001$. The Newman-Keuls procedure was used to determine which pairs of means were significantly different. This *post hoc* comparison (*MS* error = 61.9, $df = 84$, $n = 16$) indicated that the mean of treatment group 7 which received negative feedback was significantly different ($p < .05$) from the mean of group 1 (positive feedback) and the means of groups 4, 3, and 6 (neutral feedback).

For the second occasion, there was again a statistically significant difference among the seven groups, $F(6,84) = 5.83$, $p < .00004$. The result of the application of the Newman-Keuls procedure (*MS* error = 57.9, $df = 84$, $n = 16$) indicated that the mean for group 2 which received positive reinforcement was significantly different ($p < .05$) from the means of groups 6 and 7 (negative feedback) and from the means of group 4 and 5 (neutral feedback). Group 1 (positive) and group 3 (neutral) also differed significantly from group 7 (negative). However, there was no significant difference between group 7 and group 6, the latter having received less negative feedback than the former. Similarly there was no significant difference between groups 1 and 2 (both positive feedback).

For the third occasion, the means of the treatment groups differed very significantly, $F(6,84) = 11.4$, $p < .00000$. The Newman-Keuls procedure was applied (*MS* error = 56.2, $df = 84$, $n = 16$) and it was observed that the mean for group 7 (negative feedback) was significantly different ($p < .05$) from the means of all other groups including groups 5 and 6 which received negative feedback to a lesser extent. Groups 5 and 6 differed significantly ($p < .05$) from groups 2 and 3 but not from group 1 as might be expected. Group 4 (neutral feedback) differed significantly ($p < .05$) from groups 2 and 3 (positive feedback) on the third occasion.

For the means of the total of the Personal Significance Scale scores on the three occasions, there were significant differences among the seven treatment groups, $F(6,84) = 7.18$, $p < .00000$. Application of the Newman-Keuls procedure (MS error = 411.2, $df = 84$, $n = 16$) indicated that group 7 was significantly different ($p < .05$) from every other group including groups 5 and 6 which received negative feedback to a lesser extent. Group 5 (negative feedback) was significantly different from groups 1, 2, and 3 (positive feedback).

In summary, the results of extent of feedback indicate:

1. That increased extent of positive feedback was not positively associated with learning performance and self-regard with respect to mathematics in general, and increased extent of negative feedback was not negatively associated with the same dependent variables. Possible explanations for this are the same as those given for nonsignificant differences between positive and negative feedback.

2. That increased extent of positive feedback was not positively associated with self-rating on the Personal Significance Scale. Subjects receiving as much as three positive feedbacks did not differ from subjects receiving two or one positive feedbacks.

3. That, when negative feedback was given on three occasions, this had a more significant effect in decreasing self-rating on the Personal Significance Scale than giving negative feedback on one or two occasions.

In addition, the analyses revealed evidence for significant differences between positive and negative feedback on scores on the Personal Significance Scale. These findings are consistent with those found in the analysis of positive-negative feedback.

Sex. There was no significant difference between males and females on the learning performance dependent variable, $F(1,84) = 1.85$, $p > .05$. Analysis of each of the four subtests of the posttest also revealed no statistically significant differences. For the Part D subtest, however, the difference in performance between males and females approached significance, $F(1,84) = 3.30$, $p = .07$. Part D was based on information not specifically taught in the instructional material.

On the dependent variable, general self-regard with respect to mathematics, there was no statistically significant difference between males and females, $F(1,84) = 1.05$, $p > .05$.

With regard to scores on the Personal Significance Scale, women scored higher than men. This is the reverse of what was hypothesized. For the first, second, and third occasions the differences approached significance: $F(1,84) = 3.69$, $p = .06$, $F(1,84) = 2.61$, $p = .11$, $F(1,84) = 3.34$, $p = .07$, respectively. For the total scores of the three occasions there was a significant difference, $F(1,84) = 4.11$, $p < .05$. Table 5 presents the mean scores on the Personal Significance Scale for men and women by occasion. The observed sex effect is difficult to explain. Perhaps, the personal significance of feedback is greatest to persons for whom there is less of a social expectation to excel in a given task. The influence of male experimenters providing feedback should also not be discounted.

Table 5

Mean Personal Significance Scale Scores
for Males and Females

	Men	Women
First Occasion	27.9	30.7
Second Occasion	28.6	30.9
Third Occasion	28.9	31.5
All Occasions	85.4	93.1

Prior Knowledge. Two levels (high and low) of prior knowledge of number base systems were established on the basis of the subjects' performance on the Number Base Systems Pretest.

As was expected, there was a significant difference between high and low levels of prior knowledge with respect to learning performance on the posttest and for each of the four parts of the posttest. The results shown in Table 6 indicate that those subjects with high prior knowledge scored higher on the posttest than those with low prior knowledge.

Table 6

Number Base Systems Posttest Means (with F-ratios and probability levels) by Levels of Prior Knowledge

Posttest	High	Low	F-ratio and Probability
Part A	4.9	4.4	$F(1,84) = 12.00$, $p < .0008$
Part B	2.6	1.7	$F(1,84) = 14.98$, $p < .0002$
Part C	3.7	3.2	$F(1,84) = 6.65$, $p < .01$
Part D	12.3	8.0	$F(1,84) = 49.46$, $p < .0000$
Total	23.6	17.3	$F(1,84) = 51.30$, $p < .0000$

There was also a significant difference in general self-regard with respect to mathematics between subjects with high and low levels of prior knowledge, $F(1,84) = 12.3$, $p < .0007$. Subjects with high and low prior knowledge obtained mean scores of 97.7 and 81.6, respectively. Thus high prior knowledge was associated with high general self-regard with respect to mathematics.

With regard to scores on the Personal Significance Scale, there were no significant differences between subjects with high and low prior knowledge. Results of the analyses arc shown in Table 7.

Table 7

Personal Significance Scale Means (with F-ratios and probability levels) by Levels of Prior Knowledge

Occasion	High	Low	F-ratio and Probability
First	28.7	29.9	$F(1,84) = .63$, $p > .05$
Second	29.8	29.6	$F(1,84) = .01$, $p > .05$
Third	30.7	29.7	$F(1,84) = .48$, $p > .05$
Total	89.2	89.3	$F(1,84) = .00$, $p > .05$

In summary, subjects with a high level of prior knowledge had significantly higher learning performance and self-regard with respect to mathematics than subjects with low prior knowledge. It is interesting to note that there were no significant differences when the dependent variable had no relation to specific cognitive learning aspects.

Interaction of Positive-Negative Feedback with Sex. There was no significant interaction between the types of positive-negative treatments and the sex categories on any of the criterion measures. Women were expected to be affected differentially by the treatments. The F-ratio and probability level of the posttest analysis was $F(6,84) = 1.71$, $p > .05$. On the Math Opinion Instrument it was $F(6,84) = .32$, $p > .05$. The statistical test of the total score on the Personal Significance Scale was $F(6,84) = .98$, $p > .05$.

Interaction of Positive-Negative Feedback with Prior Knowledge. For the dependent variable, general self-regard with respect to mathematics there was a significant interaction of feedback treatment with prior knowledge, $F(6,84) = 2.30$, $p < .04$. Figure 6 is a graphical representation of the mean scores on the Math Opinion Instrument of treatments by prior knowledge presented in Table 8.

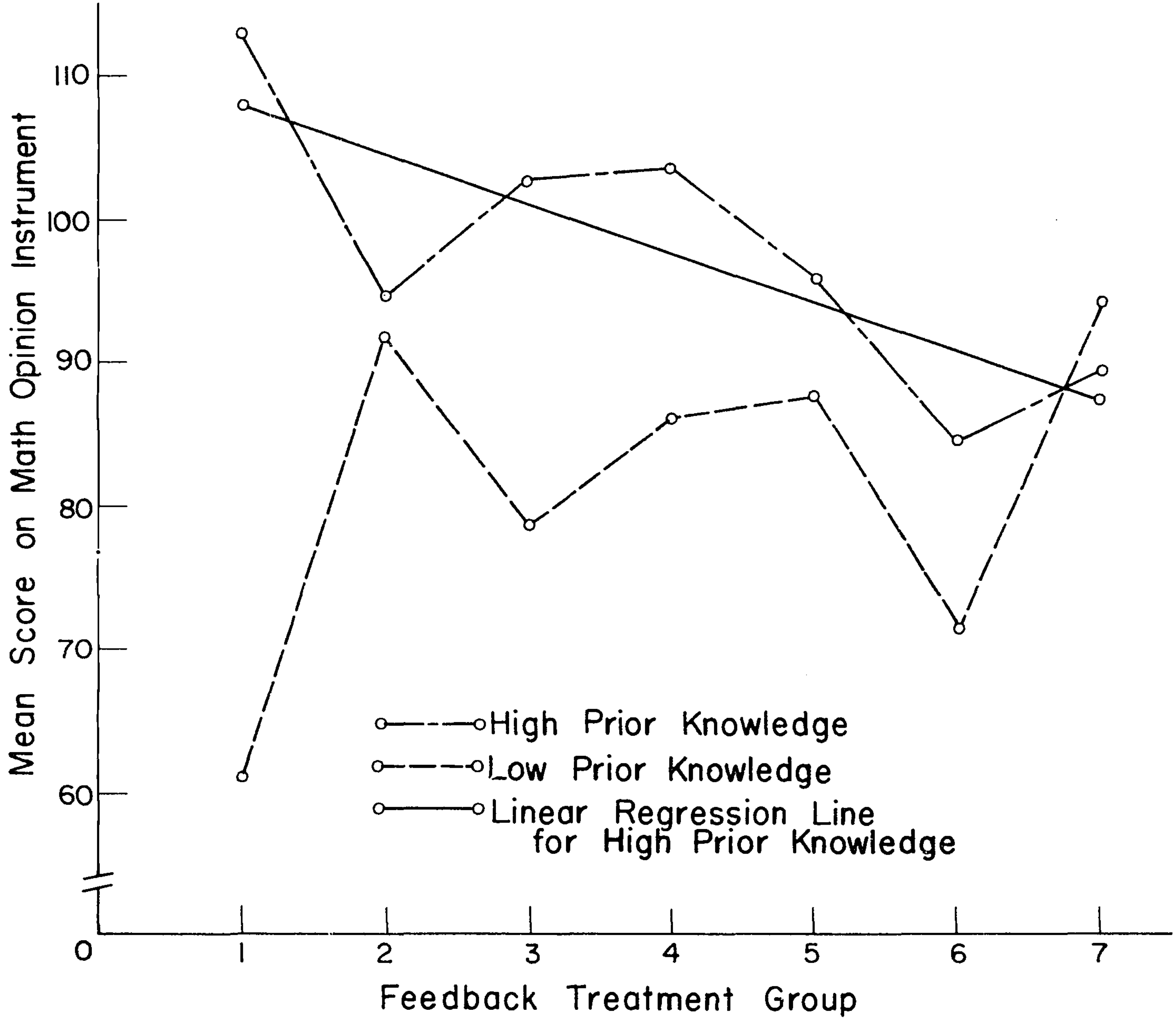

FIG. 6. Interaction of prior knowledge with feedback treatment on math opinion instrument.

Table 8

Mean Scores on the Math Opinion Instrument of Treatment Groups by Level of Prior Knowledge

Prior Knowledge	Treatment Group						
	1	2	3	4	5	6	7
High	112.9	94.6	102.7	103.6	96.1	84.6	89.5
Low	61.0	91.9	78.5	86.1	87.9	71.6	94.4

There is a downward trend in self-regard for subjects with high prior knowledge as the feedback from the experimenters changed from positive to neutral to negative. This trend is a significant linear trend, $F(1,49) = 4.43$, $p < .05$, and the departure from linearity is not significant $F(5,49) = .5457$, $p > .05$. Figure 6 shows the linear regression line.

On the other hand there is no significant linear trend, $F(1,49) = 2.68$, $p > .05$, for subjects with low prior knowledge, and no significant departure from linearity, $F(5,49) = 2.18$, $p > .05$. Thus there is no significant trend. It could be expected that as the feedback changed from positive to neutral to negative that the subjects' mean scores would show a downward trend. Presumably subjects with low prior knowledge were receiving negative feedback from the instructional materials and this counteracted the positive feedback from experimenters. Negative feedback from experimenters possibly confirmed subjects' view that they were doing poorly on the instructional materials. Subjects with high prior knowledge viewed the feedback as a confirmation of their own self-regard assessments, and negative feedback from the experimenters put into question their positive self-regard.

Conclusions

The purpose of this experiment was to ascertain the extent to which self-regard and learning performance are influenced by the type and extent of feedback received during stages of a mathematical learning activity.

These results indicated that the type of feedback (positive or negative) had a significant effect on subjects' view of the personal significance of the feedback. Subjects receiving positive feedback rated the personal significance of the feedback positively, and subjects receiving negative feedback rated the personal significance of the feedback negatively. Furthermore, first occasion positive feedback had greater effects than negative feedback, but continued positive feedback did not differ significantly from the effects of an initial positive feedback. Continued negative feedback had an increasing negative effect on immediate personal significance of the feedback. Finally, negative feedback had a significant negative effect with respect to general self-regard in mathematics for subjects with high prior knowledge of number bases.

Experiment III

Purpose

The general purpose of this experiment was to ascertain the effects of presenting sets of introductory mathematical learning materials which are differentially structured with respect to a concrete-abstract dimension. The effects of the adult learner's subject matter background and sex on learning and transfer were also ascertained.

Rationale

The findings by Ausubel (1960), Ausubel and Fitzgerald (1961b, 1962), Ausubel and Youssef (1963), Fitzgerald and Ausubel (1963), Grotelueschen (1967), Grotelueschen and Sjogren (1968), and Scandura and Wells (1967) indicate that the learning of meaningful material can be facilitated through the use of introductory materials.

The findings of Ausubel and his associates have substantiated the influence of introductory material structured at a high level of abstraction, generality, and inclusiveness on cognitive structure. The evidence supports the assumption that relating new information to an existing cognitive structure facilitates the subsequent learning and retention of related meaningful material.

In particular, when new material was completely unfamiliar to the learner, expository introductory material appeared to provide a conceptual framework for the incorporation of the new material (Ausubel, 1960; Ausubel and Fitzgerald, 1962). On the other hand, when new material was substantially unfamiliar but relatable to concepts in the learner's cognitive structure, comparative introductory material appeared to increase the ability of the learner to discriminate between relevant aspects of the unfamiliar material and existing information in cognitive structure (Ausubel and Fitzgerald, 1961b; Ausubel and Youssef, 1963; Fitzgerald and Ausubel, 1963). However, when the unfamiliar learning material was unrelatable or conflicted with general background knowledge regarding the topic, the use of introductory material appeared to benefit only those learners with more background knowledge or whose cognitive structure was more clear and stable (Ausubel and Fitzgerald, 1962; Fitzgerald and Ausubel, 1963).

In learning completely unfamiliar material, evidence was obtained by Ausubel and Fitzgerald (1962) which indicated that the use of introductory material was more beneficial for learners of low ability. Grotelueschen (1967), however, found evidence to suggest that the reception of introductory materials which were presented at a high level of abstraction, generality, and inclusiveness appeared to have a limited effect for adult learners who had less ability and who had no background knowledge regarding the learning topic. In fact, the facilitative effects of introductory materials occurred primarily with adults of superior ability.

In contrast to presenting introductory materials at a high level of generality and abstraction, Scandura and Wells (1967) presented introductions at a more concrete level. They found that the administration of concrete introductions prior to the study of abstract mathematical concepts facilitated the learning and application of the principles inherent in the mathematical material. They also found evidence which suggests that the effectiveness of concrete introductions may decrease as the learner's familiarity with the learning topic or related topics increases. That is, the effects of introductory material may be attenuated by prior knowledge. Ausubel (1960) also concluded that subjects who have a general familiarity with the content of learning material may not benefit from highly abstract introductory material because the prior relevant knowledge may act as an organizer in itself.

The previously cited studies seem to suggest that the extent to which abstract or concrete introductory materials are facilitating is dependent upon such factors as the level and difficulty of the learning material as well as relevant subject matter knowledge of the learner. To illustrate, if the substantive aspects of a learning topic are presented at an abstract level in the form of introductory materials, then the learners who have no prior knowledge of this topic and who cannot relate it to existing knowledge would not be able to profit from the introductory material. According to Ausubel, they would not have an adequate cognitive structure for the incorporation of the abstract information in the introductory material. It is assumed that if the introductory material does not enhance the clarity and stability of a learner's existing cognitive structure, then the subsequent learning of related material will also not be facilitated. It would also be expected that persons who have prior subject matter knowledge would be able to benefit more from the abstract introductory material.

This suggests that learners who do not have sufficient background in a subject matter would probably benefit more from abstract material if they were first exposed to introductory material presented at a more concrete level. This procedure would presumably provide a framework for the integration and incorporation of more abstract material. Because, if completely unfamiliar material is used, then the introductory material as a design of high abstraction, generality, and inclusiveness, becomes meaningless (McDonald, 1964). For example, if the learners in the Grotelueschen (1967) study had received the base ten condition prior to either the base seven or principles conditions, then a greater facilitative effect of these conditions on the subsequent base four learning task would have been expected.

Evidence regarding the facilitative effect of relevant subject matter background knowledge on the subsequent learning and retention of unfamiliar material indicated that learners with more background knowledge in a general subject matter field obtained significantly higher scores on tests covering the related learning material (Ausubel and Fitzgerald, 1961b; Ausubel and Fitzgerald, 1962; Ausubel and Youssef, 1963; Fitzgerald and Ausubel, 1963). This dependence of learning and retention on related subject matter knowledge was also supported by data regarding the facilitative effects of initial learning on sequentially presented material (Ausubel and Fitzgerald, 1962) and on the learning of parallel material (Ausubel and Youssef, 1963).

Although little direct evidence regarding the effects of sex on learning and retention has been presented in the previously reviewed research investigations, Ausubel (1960) found in a preliminary analysis of retention scores on a passage dealing with the metallurgical properties of plain carbon steel that men performed better than women. Grotelueschen (1967) found significant differences between men and women on a posttest measure, even when the effects of intelligence, age, and prior subject matter knowledge were controlled. Men performed consistently better than women, especially when application of the number base principles was required. This finding added empirical support to previous research evidence (e.g., Billings, 1934; Guetzkow, 1951; Sweeney, 1953) which indicated that men perform better than women in problem solving activities. Although Scandura and Wells (1967) did not control for sex differences, it is of interest that the facilitative effects of concrete introductions on an abstract mathematical topic was achieved by a sample which was predominantly (96 per cent) women.

Hypotheses

The following hypotheses were tested in this experiment.

1. There is a significant difference between the sex categories. It is expected that the men will perform better on the criterion measures than the women.

2. There is a significant difference among the subject matter background categories. It is expected that persons with more prior subject matter background will perform better on the criterion measures than those with less background knowledge.

3. There is no significant difference among the sets of introductory learning materials. No differences are expected between introductory materials structured to provide relevant concrete information and introductory materials abstractly structured.

4. There is a significant interaction among the sets of introductory materials and the sex categories. It is expected that women will benefit more than men from the set of introductory materials which is structured to provide the greatest degree of relevant concrete information, but less than the men on abstractly structured material.

5. There is a significant interaction among the sets of introductory materials and the subject matter background categories. It is expected that those persons with less subject matter background will benefit more from the set of introductory materials which is structured to provide the greatest degree of relevant concrete information than will those with a high degree of subject matter background. The persons with a higher degree of subject matter background will profit most from abstractly structured introductory materials.

Method

Subjects. The subjects for this experiment consisted of 72 paid young adults who resided in a midwestern city. These subjects had scored within a desired range on a Number Base Systems Pretest (Appendix A) and were enrolled as upper-level students in a major university.

Design. The experimental design was a fixed effects 2 x 3 x 2 factorial design. Within two levels of sex and three levels of prior knowledge of number bases, subjects were assigned at random to one of two sets of introductory materials.

Treatments. Levels of the second factor in the design, prior knowledge, were established on the basis of the Number Base Systems Pretest. The twenty items on this test were all five-option multiple choice, requiring subjects to identify face and place values of numerals in numeral sets in various bases, and to transform numbers in bases less than ten to base ten. Subjects were classified as *low* if they scored nine or below, *medium* if they scored ten to fourteen, and *high* if they scored fifteen to eighteen.

The two sets of instructional materials which served as the third factor in this experiment were linear self-instructional programs, each 150 frames in length. Program 1 (used in Experiment II) presented information on the base ten numeration system (frames 1-38); on the base seven numeration system, including transformations from base seven to base ten but giving instruction on base seven only (frames 39-90); and on principles of number bases (frames 91-150). It was felt by the experimenters that this program was structured so that it progressed from concrete information (base ten) to abstract information (principles of number bases). Program 2 consisted of the same 150 frames, ordered to deal with principles of number bases throughout, i.e., "base ten" and "base seven" frames served as examples of various basic principles of number bases. Minor editing of less than ten per cent of the Program 2 frames was necessary for continuity. For example, in Program 1, frames 12 and 13 introduce the idea of face value; frames 14 and 15 discuss base ten numerals; and frame 16 discusses grouping in base ten. In Program 2 frames 12 and 13 are identical to Program 1 (i.e., they introduce the idea of face value); but frames 14 through 18 expand on the idea of face value and supply examples from bases other than base ten.

Dependent variables. Two dependent variables were used in this study and were intended to assess the effectiveness of the instructional materials. They were combined in one instrument, the Number Base Systems Posttest (Appendix G). Sections A, B, and C of the Posttest were combined to form the first dependent variable--a test of *direct learning*. This measure consisted of the direct learning that occurred from the instructional treatments. Or to say it another way, it was a measure of the introductory materials treatment effects. A maximum score of thirteen was possible on this dependent variable. Section D, Part A of the Posttest (the second dependent variable) was a computation test which required the subjects to apply the principles they learned by having them add, subtract, multiply and divide numbers in various bases. It was a test consisting of *applicational transfer learning* because subjects were asked to apply principles to problems for which they had not received specific instruction. Part B of Section D assessed information similar to Section C (converting numerals into base ten).

Procedure. Subjects selected for the experiment on the basis of sex and pretest score were invited to attend one of several two hour sessions. Subjects had been randomly assigned to one of two treatment groups, within levels of pretest scores and sex. The subjects worked at their own pace through the instructional materials. The average time to complete the instructional materials was 66 minutes. Upon completion of the learning materials, the subjects were administered the Posttest. Upon completion of the Posttest, the subjects were paid and were free to leave. Most subjects completed all aspects of the experimental session within 110 minutes.

Results and Discussion

The following analyses and their discussion relate to the hypotheses of this experiment.

Sex. The difference between the groups on the direct learning dependent variable was not significant, $F(1,60) = 1.83$, $p > .05$. However, it did approach significance on the applicational transfer dependent variable, $F(1,60) = 3.49$, $p = .06$. In both instances men outscored women. The mean scores on the dependent variables for groups are shown in Table 9. It is interesting to note that the

Table 9

Mean Scores on Dependent Variables by Sex

	Direct Learning	Applicational Transfer
Men	11.2	5.8
Women	10.7	5.1

difference between men and women, although not statistically significant by conventional standards, was more marked on the applicational transfer portion of the posttest. This finding is consistent with previous research where application of number base principles was required (Grotelueschen, 1967).

Prior Knowledge. As was expected, the main effect for prior knowledge was highly significant on the direct learning $F(2,60) = 9.92$, $p < .0002$, and the applicational transfer, $F(2,60) = 12.88$, $p < .00002$, criterion measures. The means for the prior knowledge groups by criterion measure are provided in Table 10. Those subjects who knew the most about number bases to begin with, scored highest on the criterion measures. Those who knew least, scored the lowest. This main effect, however, is of little substantive consequence for the present study. It was included, primarily, for the purpose of ascertaining its interaction with the experimental treatments.

Instructional Materials. As predicted, the main effect for instructional materials was not significant on the direct learning, $F(1,60) = .86$, $p > .05$, and the applicational transfer, $F(1,60) = .10$, $p > .05$ dependent variables. Program 1, which progressed in structure

Table 10

Mean Scores for Prior Knowledge Groups by Dependent Variable

	Direct Learning	Applicational Transfer
Low	9.92	4.25
Medium	11.00	5.75
High	12.04	6.41

from concrete to abstract, had no differential effect from Program 2, which was structured more abstractly throughout. Again, this factor was included primarily to ascertain its interaction with the other factors.

Interaction of Sex X Instructional Materials. There was no significant interaction between sex and instructional materials on the direct learning, $F(1,60) = .86$, $p > .05$, and the applicational transfer $F(1,60) = 1.19$, $p > .05$, dependent variables. Men outscored women slightly on both dependent variables regardless of which set of instructional materials they received.

Interaction of Prior Knowledge X Instructional Materials. The interaction between prior knowledge and instructional materials was statistically significant on the applicational transfer dependent variable, $F(2,60) = 3.08$, $p < .05$, but was not significant on the direct learning criterion $F(2,60) = .01$, $p > .05$. Within the direct learning test, the subjects who received the concrete to abstract instructional materials (Program 1) scored slightly higher across all levels of prior knowledge. In contrast, on the applicational transfer test those subjects with little prior knowledge did better when given concrete instructional materials, whereas subjects with much prior knowledge benefited most by the abstract (principle) materials. This interaction is shown in Figure 7. The different effects observed for the two criteria might be explained by a ceiling effect noted on the direct learning measure (intended to assess the direct instructional effects) or by the fact that both instructional material treatments did an excellent job of presenting the material to all subjects. Another plausible explanation is that instructional treatments designed differentially with respect to level of abstraction found the applicational transfer criterion to be more compatible for observing effects. That is, effects of material structured according to principles of a topic can only be observed if the criterion measure allows for the principles to be observed.

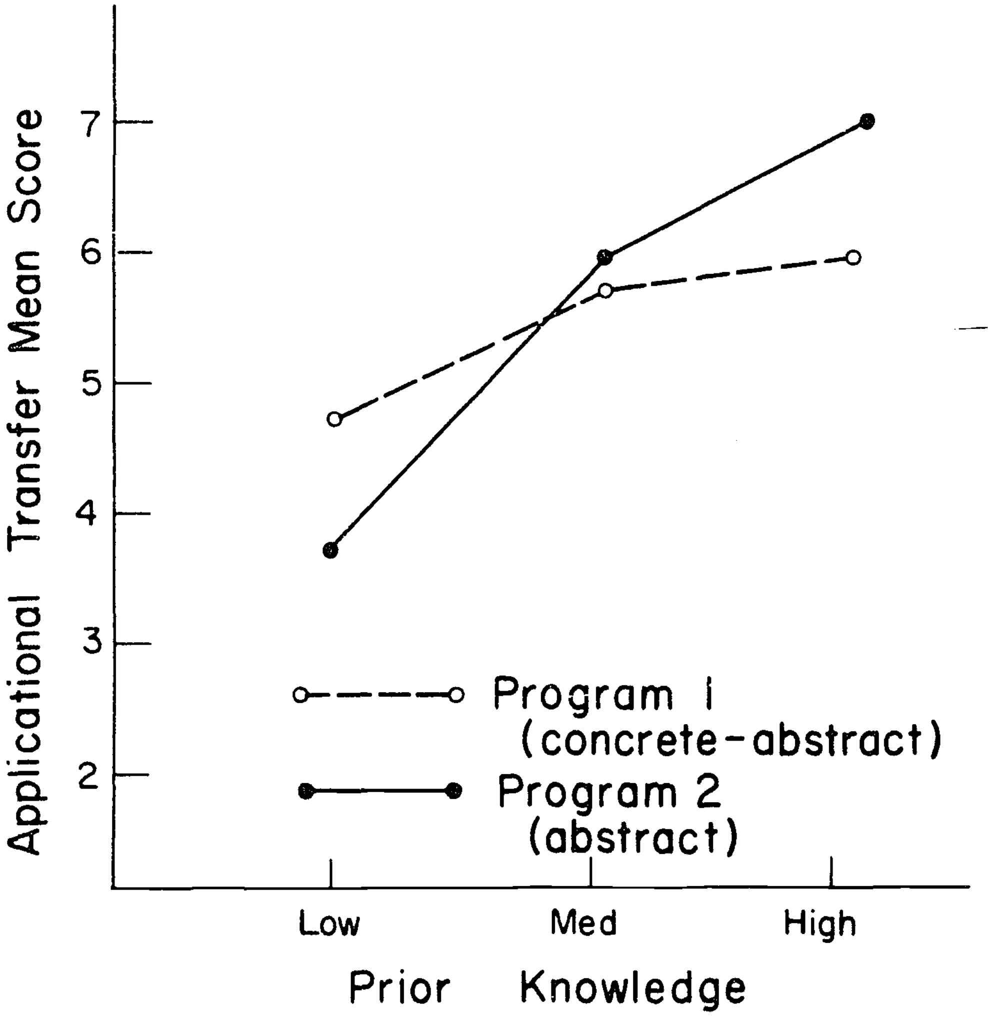

FIG. 7. Mean performance on applicational transfer as a function of prior knowledge and instructional material.

Conclusions

In this study, differentially structured instructional materials were administered to subjects of both sexes and with three levels of prior knowledge of number bases.

The results indicated that transfer or application to tasks measured by a general test of number base computational skills was differentially facilitated by the instructional materials depending on level of prior knowledge. That is, subjects with little prior knowledge benefited most from materials structured to progress from concrete to abstract information. In contrast, subjects with a high level of prior knowledge benefited more from materials that were abstract throughout.

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APPENDIX A
NUMBER BASE SYSTEMS PRETEST

Name ______________________________ Date ____________________

Directions: Circle the letter of the correct answer for the following:

1. In our numeration system we group by
   a. tens.
   b. hundreds.
   c. ones.
   d. thousands.
   e. all of the above.

2. In base twelve we group number ideas by
   a. six.
   b. twenty-four.
   c. four.
   d. twelve.
   e. two.

3. In base two we group by
   a. ones.
   b. twos.
   c. threes.
   d. fours.
   e. fives.

4. The face value of 6 in our numeration system is
   a. two.
   b. four.
   c. six.
   d. eight.
   e. ten.

5. The face value of the numeral 5 in base seven means
   a. seven fives.
   b. ten.
   c. five tens.
   d. five sevens.
   e. five.

6. The face value of the numeral 9 in base seven means
   a. nine nines.
   b. nine tens.
   c. nine sevens.
   d. nine ones.
   e. none of the above.

7. In our numeration system, the place value of the second position from the right in a two digit numeral is
   a. ten thousands.
   b. thousands.
   c. hundreds.
   d. tens.
   e. ones.

8. In base two, the "1" in the numeral 10 is how many times the numeral 1 in the same base system?
   a. eight
   b. ten
   c. two
   d. one
   e. four

9. In base three, the numeral "2" in 2,101 means two
   a. twenty-sevens.
   b. nines.
   c. ones.
   d. threes.
   e. eighteens.

10. In base five, the 3 in 3,000 is how many times the 3 in 30?
    a. fifteen
    b. ten
    c. five
    d. twenty
    e. twenty-five

11. In our numeration system, the "2" in the numeral 672 means two
    a. ones.
    b. hundreds.
    c. thousands.
    d. tens.
    e. none of the above.

12. In base four, the place value of the third position from the right in a three digit numeral is
    a. one.
    b. sixteen.
    c. twelve.
    d. eight.
    e. four.

13. The "5" in the numeral 543 in base six means five
    a. ones.
    b. sixes.
    c. twelves.
    d. hundreds.
    e. thirty-sixes.

14. If you write 124 in base five the numeral 1 stands for one
    a. one-hundred.
    b. twenty-five.
    c. fifty.
    d. one.
    e. five.

15. In base nine, the numeral 3,201 has how many nines?
    a. three
    b. six
    c. zero
    d. nine
    e. one

16. In base five the numeral 10 stands for the number
    a. one.
    b. six.
    c. ten.
    d. five.
    e. none of the above.

17. In base eight the numeral 13 stands for the number
    a. four.
    b. fifteen.
    c. eleven.
    d. thirteen.
    e. nine.

18. In base three the numeral 120 stands for the number
    a. fifteen.
    b. three.
    c. eighteen.
    d. twelve.
    e. nine.

19. The base of a number system is the
    a. face value of the right digit in a number.
    b. same as the amount of numerals used minus one.
    c. distance between each of the number values.
    d. same as the number of symbols used.
    e. place value of the right digit in a number.

20. The value of the position of the "2" in the numeral 231 is the
    a. place value of the numeral.
    b. base of the number system.
    c. face and place values of the numeral.
    d. face value of the numeral.
    e. base of the number system combined with the face and place values of the numeral.

APPENDIX B
NUMBER BASE SYSTEMS POSTTEST

Name ________________________________ Date ____________________

A. Directions: Circle the letter of the correct answer for the following:

1. The face value of the numeral 5 in base seven means
    a. seven fives.
    b. ten.
    c. five tens.
    d. five sevens.
    e. five.

2. In base two, the "1" in the numeral 10 is how many times the numeral 1 in the same base system?
    a. eight
    b. ten
    c. two
    d. one
    e. four

3. In base three, the numeral "2" in 2,101 means two
    a. twenty-sevens.
    b. nines.
    c. ones.
    d. threes.
    e. eighteens.

4. In base four, the place value of the third position from the right in a three digit numeral is
    a. one.
    b. sixteen.
    c. twelve.
    d. eight.
    e. four.

5. The "5" in the numeral 543 in base six means five
    a. ones.
    b. sixes.
    c. twelves.
    d. hundreds.
    e. thirty-sixes.

6. If you write 124 in base five the numeral 1 stands for one
    a. one-hundred.
    b. twenty-five.
    c. fifty.
    d. one.
    e. five.

7. In base nine, the numeral 3,201 has how many nines?
   a. three
   b. six
   c. zero
   d. nine
   e. one

8. In base five the numeral 10 stands for the number
   a. one.
   b. six.
   c. ten.
   d. five.
   e. none of the above.

9. In base eight the numeral 13 stands for the number
   a. four.
   b. fifteen.
   c. eleven.
   d. thirteen.
   e. nine.

10. In base three the numeral 120 stands for the number
   a. fifteen.
   b. three.
   c. eighteen.
   d. twelve.
   e. nine.

B. Directions: Complete the following sentence by calculating the correct numeral for the given arithmetic operation. Express answers in the base in which the problem is stated and in base ten in the blanks to the right of each incomplete sentence. You may use the margins for computations.

	Answer Columns	
	Base in which problem is stated	Base ten
1. In base nine, 27 minus 15 equals _____.	____________	____________
2. The addition of 23 to 121 in base six equals _____.	____________	____________
3. The multiplication of 21 and 11 in base five results in an answer of _____.	____________	____________

Answer Columns

	Base in which problem is stated	Base ten
4. Dividing 30 by 3 in base seven results in an answer of _____.	____________	____________
5. In base three, the addition of 21001 to 1002 equals _____.	____________	____________
6. In base eight, 352 minus 105 equals _____.	____________	____________
7. The product of 1011 and 11 in base two is _____.	____________	____________
8. The quotient of 63 divided by 5 in base seven is _____.	____________	____________

APPENDIX C

NUMBER BASE ACHIEVEMENT TEST

Name ______________________________ Date ____________________

Directions: For each of the following numbers, write the appropriate base four numerals of the number in the corresponding blank space. The numeral 0, 1, 2, and 3 are to be used in constructing your responses. These numerals represent the numbers zero, one, two, and three respectively.

	Number	Numeral
1.	SIX	________
2.	FIVE	________
3.	SEVEN	________
4.	THIRTEEN	________
5.	SIXTEEN	________
6.	FOUR	________
7.	SEVENTY-FIVE	________
8.	TEN	________
9.	SIXTY-FOUR	________
10.	TWENTY	________
11.	TWENTY-FIVE	________
12.	EIGHT	________
13.	ELEVEN	________
14.	EIGHTY-FOUR	________
15.	NINE	________
16.	THIRTY	________

APPENDIX D
PERSONAL SIGNIFICANCE SCALE

Please rate the *personal significance of the feedback* you just received about your performance on the base ten material. Indicate your rating by circling the appropriate numeral for each scale. A neutral position is indicated by the numeral 4.

Worthless	1	2	3	4	5	6	7	Valuable
Accurate	1	2	3	4	5	6	7	Inaccurate
Vague	1	2	3	4	5	6	7	Precise
Encouraging	1	2	3	4	5	6	7	Discouraging
Critical	1	2	3	4	5	6	7	Complimentary
Honest	1	2	3	4	5	6	7	Dishonest
Unfair	1	2	3	4	5	6	7	Fair

Please rate the *personal significance of the feedback* you just received about your performance on the base seven material. Indicate your rating by circling the appropriate numeral for each scale. A neutral position is indicated by the numeral 4.

Worthless	1	2	3	4	5	6	7	Valuable
Accurate	1	2	3	4	5	6	7	Inaccurate
Vague	1	2	3	4	5	6	7	Precise
Encouraging	1	2	3	4	5	6	7	Discouraging
Critical	1	2	3	4	5	6	7	Complimentary
Honest	1	2	3	4	5	6	7	Dishonest
Unfair	1	2	3	4	5	6	7	Fair

Please rate the *personal significance of the feedback* you just received about your performance on the principles of number bases material. Indicate your rating by circling the appropriate numeral for each scale. A neutral position is indicated by the numeral 4.

Worthless	1	2	3	4	5	6	7	Valuable
Accurate	1	2	3	4	5	6	7	Inaccurate
Vague	1	2	3	4	5	6	7	Precise
Encouraging	1	2	3	4	5	6	7	Discouraging
Critical	1	2	3	4	5	6	7	Complimentary
Honest	1	2	3	4	5	6	7	Dishonest
Unfair	1	2	3	4	5	6	7	Fair

APPENDIX E
MATH OPINION INSTRUMENT

No. ______________ Name ________________________

The following statements are to help you describe yourself as you see yourself with respect to mathematics. Please respond to them as if you were *describing* yourself to yourself. *Do* not *omit* any *item*. Read each statement carefully; then select one of the seven responses listed to the right of the item. Put a circle around the response you have chosen for each statement.

	Completely False	Mostly False	More False Than True	Partly False Partly True	More True Than False	Mostly True	Completely True
1. Manipulating numbers gives me a feeling of accomplishment	1	2	3	4	5	6	7
2. Math likes me.	1	2	3	4	5	6	7
3. Numbers scare me . . .	1	2	3	4	5	6	7
4. I have trouble doing math problems.	1	2	3	4	5	6	7
5. Few people enjoy math more than I.	1	2	3	4	5	6	7
6. I do not think mathematically.	1	2	3	4	5	6	7
7. Math has many practical applications for me. .	1	2	3	4	5	6	7
8. I like math.	1	2	3	4	5	6	7
9. Studying math is usually a trying experience	1	2	3	4	5	6	7
10. I would enjoy an opportunity to learn more math	1	2	3	4	5	6	7

	Completely False	Mostly False	More False Than True	Partly False Partly True	More True Than False	Mostly True	Completely True
11. Working math problems is a waste of my time.	1	2	3	4	5	6	7
12. I am confident of my ability to work with numbers.	1	2	3	4	5	6	7
13. I do poorly in math. .	1	2	3	4	5	6	7
14. Algebraic symbols frighten me.	1	2	3	4	5	6	7
15. Arithmetic comes easy for me	1	2	3	4	5	6	7
16. I hate math.	1	2	3	4	5	6	7
17. I find it difficult to learn new mathematical concepts	1	2	3	4	5	6	7
18. I enjoy working with numbers.	1	2	3	4	5	6	7
19. Most people are more competent at arithmetic calculations thau I. .	1	2	3	4	5	6	7
20. I feel at ease doing mathematical problems.	1	2	3	4	5	6	7

APPENDIX F
NUMBER BASE SYSTEMS POSTTEST

A. Directions: Circle the letter of the correct answer for the following:

1. In base two, the "1" in the numeral 10 is how many times the numeral 1 in the same base system?
   a. eight
   b. ten
   c. two
   d. one
   e. four

2. The "5" in the numeral 543 in base six means five
   a. ones.
   b. sixes.
   c. twelves.
   d. hundreds.
   e. thirty-sixes.

3. In base five the numeral 10 stands for the number
   a. one.
   b. six.
   c. ten.
   d. five.
   e. none of the above.

4. In base eight the numeral 13 stands for the number
   a. four.
   b. fifteen.
   c. eleven.
   d. thirteen.
   e. nine.

5. In base three the numeral 120 stands for the number
   a. fifteen.
   b. three.
   c. eighteen.
   d. twelve.
   e. nine.

B. Directions: Convert the following base ten numerals into the designated bases.

1. $48_{ten} = \_\_\_\_\_\_\_\__{seven}$

2. $81_{ten} = \_\_\_\_\_\_\_\__{nine}$

3. $21_{ten} = \_\_\_\_\_\_\_\__{four}$

4. $11_{ten} = \_\_\_\_\_\_\_\__{two}$

C. Directions: Convert the following designated base numerals into base ten.

1. 100_{seven} = ________ten

2. 333_{four} = ________ten

3. 129_{twelve} = ________ten

5. 133_{twenty} = ________ten

D. Directions: Complete the following sentence by calculating the correct numeral for the given arithmetic operation. Express answers in the base in which the problem is stated and in base ten in the blanks to the right of each incomplete sentence. You may use the margins for computations.

	Answer Columns	
	Base in which problem is stated	Base ten
1. In base nine, 27 minus 15 equals _____.	________	________
2. The addition of 23 to 121 in base six equals _____.	________	________
3. The multiplication of 21 and 11 in base five results in an answer of _____.	________	________
4. Dividing 30 by 3 in base seven results in an answer of _____.	________	________
5. In base three, the addition of 21001 to 1002 equals _____.	________	________
6. In base eight, 352 minus 105 equals _____.	________	________
7. The product of 1011 and 11 in base two is _____.	________	________
8. The quotient of 63 divided by 5 in base seven is _____.	________	________

APPENDIX G
NUMBER BASE SYSTEMS POSTTEST

A. Directions: Circle the letter of the correct answer for the following:

1. In base two, the "1" in the numeral 10 is how many times the numeral 1 in the same base system?
   a. eight
   b. ten
   c. two
   d. one
   e. four

2. The "5" in the numeral 543 in base six means five
   a. ones.
   b. sixes.
   c. twelves.
   d. hundreds.
   e. thirty-sixes.

3. In base five the numeral 10 stands for the number
   a. one.
   b. six.
   c. ten.
   d. five.
   e. none of the above.

4. In base eight the numeral 13 stands for the number
   a. four.
   b. fifteen.
   c. eleven.
   d. thirteen.
   e. nine.

5. In base three the numeral 120 stands for the number
   a. fifteen.
   b. three.
   c. eighteen.
   d. twelve.
   e. nine.

B. Directions: Convert the following base ten numerals into the designated bases.

1. $48_{ten} = \_\_\_\_\_\__{seven}$

2. $81_{ten} = \_\_\_\_\_\__{nine}$

3. $21_{ten} = \_\_\_\_\_\__{four}$

4. $11_{ten} = \_\_\_\_\_\__{two}$

C. Directions: Convert the following designated base numerals into base ten.

1. 100_{seven} = ________ ten

2. 333_{four} = ________ ten

3. 129_{twelve} = ________ ten

4. 133_{twenty} = ________ ten

D. Directions: Complete each sentence (a) by calculating the answer to the given arithmetic operation in the base stated, and (b) by converting that answer into base ten.

	(a) State the answer:	(b) State the answer, converted into base ten
1. In base nine, 27 minus 15 equals . . .	________	________
2. The addition of 23 to 121 in base six equals . . .	________	________
3. The multiplication of 21 and 11 in base five results in an answer of . . .	________	________
4. Dividing 30 by 3 in base seven results in an answer of . . .	________	________
5. In base three, the addition of 21001 to 1002 equals . . .	________	________
6. In base eight, 352 minus 105 equals . . .	________	________
7. The product of 1011 and 11 in base two is . . .	________	________
8. The quotient of 63 divided by 5 in base seven is . . .	________	________