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ABSTRACT

A computer-assisted instruction (CAI) physics lesson on magnetism was supplemented with slides and film loops to provide a simulated encounter with simple magnetism experiments. Two groups of students took the CAI lesson, but one group viewed the simulated experiments, while the other group performed the actual laboratory experiments. Since neither of the instructional modes led to posttest performance indicating lesson mastery, the data was further examined in an attempt to identify program weakness. Possible sequence-related difficulties were considered in the light of evidence pertaining to positive transfer. A hierarchy of "conceptual levels" was predicted for the lesson and used as a basis for an analysis of transfer effects. Although inconclusive, the evidence seemed to indicate positive transfer in the predicted manner and suggested resequencing the lesson as an initial step toward making learning optimal. Student opinion favored the use of the simulated experiments as a welcome change of pace from usual classroom activities. (JY)

CAI CENTER

TECH MEMO

MULTI-MEDIA SIMULATION OF LABORATORY EXPERIMENTS IN A BASIC PHYSICS LESSON ON MAGNETISM

Darol Graham, Guenter Schwarz, and Duncan Hansen

Tech Memo No. 25
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Project No. NR 154-280
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A post hoc analysis of learning by objective was conducted to determine the existence of transfer effects in accordance with a predicted hierarchy of conceptual development. Although inconclusive, the evidence appeared indicative of positive transfer in the predicted manner and suggested resequencing of the lesson as an initial step toward making learning optimal.

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ABSTRACT

Laboratory and simulated laboratory experiences were developed and integrated with a CAI physics lesson on magnetism. The relative effectiveness of actual and simulated concrete referents as an aid to learning abstract concepts and principles was investigated for college students in a basic physics course. No differences were detected between the two conditions with respect to posttest performance or total instructional time.

A post hoc analysis of learning by objective was conducted to determine the existence of transfer effects in accordance with a predicted hierarchy of conceptual development. Although inconclusive, the evidence appeared indicative of positive transfer in the predicted manner and suggested resequencing of the lesson as an initial step toward making learning optimal.

MULTI-MEDIA SIMULATION OF LABORATORY EXPERIMENTS IN A BASIC PHYSICS LESSON ON MAGNETISM

Considerable interest has been generated concerning the use of environmental simulation to facilitate learning. The term simulation has been ascribed a number of meanings and connotations but in its most general sense refers to the representation of reality. In the context of the present study, the simulated environment mode denotes an instructional method designed to provide individual students with a substitute for the manipulation of specific laboratory apparatus. More precisely, a computer-based instructional system has been supplemented with slides and film loops to provide a simulated encounter with simple magnetism experiments. Feasibility studies of this nature appear to be warranted from an examination of the potential advantages afforded by simulation of laboratory experiences in science education.

Simulation may offer relief from some of the problems involving space, personnel, and equipment inadequacies arising from rapidly growing enrollments in many schools. Brubaker, Schwendeman, and McQuarrie (1964) identified advantages of filmed experiments over the crowded, mass production of a typical chemistry laboratory for non-majors. Most important of these advantages is the familiartiy provided with experiments involving principles that the students are capable of understanding but requiring advanced techniques and equipment which are unavailable to the beginner.

Zinn (1968) suggested that simulation permits exploration of situations which may be too expensive, too dangerous, or too time consuming in real life. Also, the use of simulation for teaching theoretical concepts which are at the higher levels of abstraction should be considered. Blum and Bork (1969) point to the presentation of experience possibilities in a spacetime world for relativity studies or a non-Newtonian universe for experiments in mechanics. Relevant laboratory experiments are unavailable for such theoretical inferences.

Additionally, simulation may be able to alleviate some of the disadvantages that accompany the conventional use of the laboratory: (1) lack of coordination of instructional units between the classroom and the laboratory; (2) regimentation of a fixed meeting time for the laboratory and its being of limited duration; (3) scheduling of experiments on the basis of equipment availability rather than student need; (4) relegation of the laboratory administration to graduate students with limited experience and unproven competence; and (5) inefficient use of time while obtaining, maintaining, and assembling apparatus.

While simulation appears to offer many advantages over traditional laboratory experiences, it should be remembered that an instructional mode represents a means, not an end. Many of these advantages would have little merit unless simulation can facilitate at least an equivalent degree of learning. An investigation of the extent of learning requires prior identification of the specific learning skills of interest. It should be possible to identify some of these skills through an examination of objectives of laboratory instruction.

The laboratory movement has evolved from a need to implant specific manipulative capabilities in the prospective scientist's repertory of skills. Since laboratory science has become a common requirement for the nonmajor, educators have been forced to identify new objectives to justify the existence of the laboratory. These objectives include, among others, facilitation of concept and principle learning, development of problem solving capabilities, and inculcation of scientific attitudes. Regardless of the expressed objectives, achievement by the nonmajor is commonly measured in terms of concept and principle learning.

The relative importance of concept and principle learning as a laboratory objective may be debatable, but as long as educators continue to test for achievement in this area, the emphasis upon design of instruction to attain this objective should be commensurate. The acceptance of this objective as a reasonable one for purposes of investigation necessitates consideration of the operational usage of the terms "concept" and "principle."

The distinction between concepts and principles appears to be unclear to most science educators. Many of them would tend to agree with Smith (1966) that it is impossible to sharply differentiate principles, and even facts, from concepts. Greater clarity can be found when one turns to the learning theorists. Ausubel (1968) defined concepts as "unitary generic or categorical ideas" while principles are "composite ideas that involve meaningful relational combinations of concepts that are propositional in nature." Gagné (1965) made a similar distinction between the two terms but displayed more interest in their hierarchical relationship. The problem of semantics for science educators may not be one of great significance since both concepts and principles are used to organize, to summarize, and to generalize. Perhaps of greater relevance in the design of science instruction is the degree of complexity or level of abstraction. This would appear to be in agreement with the assertion by Gagné (1968) that "abstract concepts are formally similar to principles."

Novak (1969) suggested the construction of a "taxonomy of conceptual levels" and contended that such a taxonomy would provide a natural scheme for organizing the subsuming processes described in the learning theories of Ausubel (1968). The closest approximation to this suggestion appears to be the "structure of organized knowledge" presented by Gagné (1965). This structure suggests an ordering of principles in the form of hierarchies which display the dependence of higher-level principle learning upon prior learning of subordinate principles and of concepts. More recently, Gagné (1968) has suggested that "learning hierarchies are descriptions of the relationships of positive transfer among intellectual skills, but that they are not descriptions of how one acquires verbalizable knowledge." He has thus been careful to differentiate "what the individual can do" from "what the individual knows." In this skill context, the terms "concept" and "principle" would refer to the capabilities of classifying and rule-following. This distinction between process and content appears to be one of considerable significance for design of instruction and measurement of learning outcomes.

Gagné (1968) also emphasized that verbalizable knowledge and even intellectual skills can be acquired by learners somewhat independently of presentation sequence. However, learned intellectual skills will be found to generate positive transfer in an ordered fashion regardless of presentation sequence. This statement is not meant to imply that positive transfer is unaffected by presentation sequence. One goal of lesson development should be the identification and utilization of an optimal instructional sequence to enhance transfer among learning events.

The present study was designed to measure the relative effectiveness of actual and simulated laboratory experience for enhancing the learning of a basic physics lesson on magnetism. Since neither of these instructional modes led to posttest performance that would be indicative of lesson mastery, the data was further examined in an attempt to identify program weaknesses. It was deemed appropriate to consider possible sequence-related difficulties in light of evidence pertaining to positive transfer. Specifically, a hierarchy of "conceptual levels" was predicted for the lesson and used as a basis for an analysis of transfer effects. The control provided by computer simulation readily permits the alteration of presentation sequence for subsequent attempts to identify an optimal sequence and its relation to positive transfer.

Review of the Literature

The simulated environment mode presents many problems in the realm of design and development. The types of models described by authors such as McMillan and Gonzales (1968) and Evans, Wallace, and Sutherland (1968) are generally inappropriate since they are basically concerned with systems utilizing mathematical models. The present investigation has required extensive trial and error procedures to develop realistic simulations of laboratory experiences. Perhaps the documentation of this process will prove of value to future attempts of this nature.

Instructional use of the computer. Considerable evidence has been accumulated to demonstrate the effectivenss of computer-assisted instruction (CAI) as a learning mode. Hickey (1968) has reviewed the development, application, and results of instructional uses of the computer in a recent survey of the CAI literature. Additional reviews of the educational applications of computers have been presented in the books by Bushnell and Allen (1967) and by Atkinson and Wilson (1969). There appears to be little doubt that CAI offers extensive potential as an instructional tool.

Specific investigations in the science area include the Intermediate Science Curriculum Study (ISCS) by Snyder, Flood, and Stuart (1967) and the CAI college physics course by Hansen, Dick, and Lippert (1968). The latter study reported a general superiority of CAI instruction over conventional classroom instruction; however, an analysis of learning by topics revealed instructional weaknesses on certain CAI lessons. These weaknesses have been attributed to inappropriate media selection by Schwarz and Kromhout (1968). They have posited that student performance on these lessons could be improved by the addition of laboratory as alternate medium. This appears to be in accord with Ausubel's (1968) suggestion that even mature students would tend to function at a relatively concrete or intuitive level when confronted with unfamiliar concepts and would benefit from concrete-empirical props to generate intuitive meanings.

Simulation of laboratory experiences. Recent studies indicate that laboratory simulation provides an effective medium for instruction. Wing (1965) cites pre- to posttest gains for concept learning through the use of multi-media simulation of physics experiences. As a result of additional positive results, Wing (1968) has advocated considerably more study of ways in which simulation techniques can be used in science instruction. He further recommended departure from traditional methodology to devise improved methods of instructing students in science through the use of simulation.

The chemistry project conducted by Lagowski and Bunderson (1968) at the University of Texas appears to have the greatest relevance to the present experiment. A preliminary field evaluation indicates that computer simulation of qualitiative analysis experiments incorporated in a CAI course produces the same terminal behaviors as the traditional method with considerable saving in student time. Other chemistry simulations are being developed but field test results have yet to be presented.

In a survey of computers in physics instruction, Schwarz, Kromhout, and Edwards (1969) report the development of a set of electricity and magnetism experiments at the Thomas J. Watson Research Center of IBM and the devlopment of experiments in elementary physics and chemistry by Science Research Associates. A number of more sophisticated laboratory simulations have been reviewed by Blum and Bork (1969) in another survey. These innovations include a simulated high energy accelerator, a simulated mass spectrometer, and the simulation of radioactive decay. The instructional potential of these laboratory simulations appears to be substantial, but learning data is generally lacking at present.

Learning hierarchies. Convincing evidence has been accumulated in studies of transfer of learning to substantiate the existence of learning hierarchies. Beginning with the Gagné and Paradise (1961) study involving algebraic equation-solving, Gagné has amassed considerable data that suggest hierarchical dependencies in mathematics and science. Kingsley and Hall (1967) have reported substantial amounts of positive transfer of subordinate skills to the final tasks in a derived hierarchy of conservation skills. In another study involving conservation tasks, Beilin, Kagan, and Rabinowitz (1966) found prior classification training to provide greater positive transfer than verbal training to a task involving water-level representation. Scandura and

Wells (1967) showed positive transfer effects from organizers in the form of relevant rules used in mathematical games, to learning materials in mathematics and topology.

Sequence of instruction. Although intuitively appealing, the literature provides scant evidence of any dependence of instructional sequence upon logical ordering. In fact, studies such as that of Payne, Krathwohl, and Gordon (1967) suggest just the opposite. These investigators found that the scrambling of frames in three programmed lessons in educational measurement did not affect performance on criterion measures of learning and retention. These results were in agreement with earlier studies of this nature conducted by Roe, Case and Roe (1962) and by Levin and Baker (1963). Other examples could be cited, but the results are similar.

Gagné (1968) implied that such findings merely serve to emphasize the need to clearly distinguish between intellectual skills and verbalizable knowledge when ordering a sequence of instruction. Briggs (1968) suggested the determination of optimal sequence through the process of task analysis followed by empirically based revision. He has identified a need to perform experiments of this type in many subject matter areas.

Statement of the Problem

The present investigation involved the development of a lesson on magnetism in the simulated environment mode to parallel an existing laboratory version of the same lesson. The two versions were field tested simultaneously to determine their relative effectiveness. Effectiveness was measured by a posttest derived from performance objectives identified for the lesson and by the total time required for instruction. Due to the lack of mastery of the learning materials by students instructed by either version, the data were also examined to determine the existence of transer effects in accordance with a predicted hierarchy of conceptual development. Evidence of positive transfer was of interest for sequence modification during subsequent revision.

Rationale of the Study

In an attempt to reduce the difficulties encountered by college students in an unfamiliar subject-matter area, concrete referents in the form of simple experiments were added to a CAI physics lesson. It was assumed that concrete empirical props and relevant analogies would facilitate the formulation of abstract concepts and principles, even for mature learners, as suggested by Ausubel (1968). Based on this assumption, it was theorized that the simulated environment mode would provide concrete referents for abstract concept and principle learning equally as effectively as laboratory manipulation. Additionally, if simulation could facilitate equivalent learning while conserving the time required to set up and manipulate the laboratory apparatus, the simulated environment mode would prove more efficient.

Research Questions

The following research questions have been identified relative to the present study:

(1) Do differences exist in the instructional effectiveness of a laboratory-supplemented CAI lesson compared to a similar lesson augmented with simulated laboratory experiences as measured by a posttest based on objectives related to concept and principle learning?

(2) Are there differences in the time required for students to complete a CAI magnetism lesson that is supplemented with laboratory experiences compared to a similar lesson that is supplemented with simulated laboratory experiences?

(3) What are the opinions of students concerning the effectiveness and desirability of receiving instruction in physics by CAI supplemented with either actual or simulated laboratory experiences?

(4) What evidence of positive transfer within a CAI lesson on magnetism can be obtained from an objective-based posttest to suggest the existence of a learning hierarchy?

Method

Learning Materials

Lesson 23: Magnets and Magnetism from the FSU-CAI Physics Project (Hansen, et al., 1968) was completely revised as proposed by Schwarz and Kromhout (1968). The format was altered to include the performance of simple experiments at appropriate times within the lesson. The experiments added to the lesson were related to the field and force properties associated with magnets and magnetism. Further revision of the lesson followed on the basis of the results of empirical data obtained during subsequent formative evaluation.

For the present experiment, the identification of performance objectives for the previously developed magnetism lesson was desired. Since objectives for this lesson were unavailable, it was necessary to derive these objectives from an analysis of the laboratory version of the learning materials and have them substantiated by the original authors. Based upon the derived objectives, test items were prepared and the learning materials were modified. Lesson modification involved the replacement of all laboratory manipulations by seemingly appropriate simulated experiences.

The decision to modify an existing lesson was based upon several advantages which use of these materials had to offer. First, the authors had been closely associated with the Physics 107 program at FSU and were well aware of the course objectives and content and of the student capabilities. The use of these materials provided an opportunity to capitalize upon the extensive experience of the authors in the development of such materials. Second, since this lesson was designed to fulfill the same objectives as the corresponding lesson in Physics 107, coordination of the data collection with the time schedule of the physics class ensured the availabiltiy of subjects with the requisite entry behaviors. Finally, the laboratory experiments used in this lesson could be readily simulated within the technical and time constraints imposed upon the investigation.

Modification of the existing instructional sequence was highly restrictive in nature. For experimental purposes, it was desirable to have the two versions of the lesson identical in every respect except one, namely, the laboratory experiences. Each manipulative task was replaced with an appropriate computer simulation. Color slides were utilized to display the simulated apparatus and its manipulation. All verbal exposition and Socratic dialogue that did not pertain to specific laboratory experimentation remained constant.

Task Analysis

The physics lesson used in the present study can be described as an instructional sequence designed to enable the student to formulate a model for magnetism which explains, or is consistent with, observable magnetic phenomena. An analysis of the existing laboratory version of the lesson identified the series of events contained in Appendix A. Further analysis of these events suggested their organization into the four major learning tasks found in Figure 1. These objectives and their

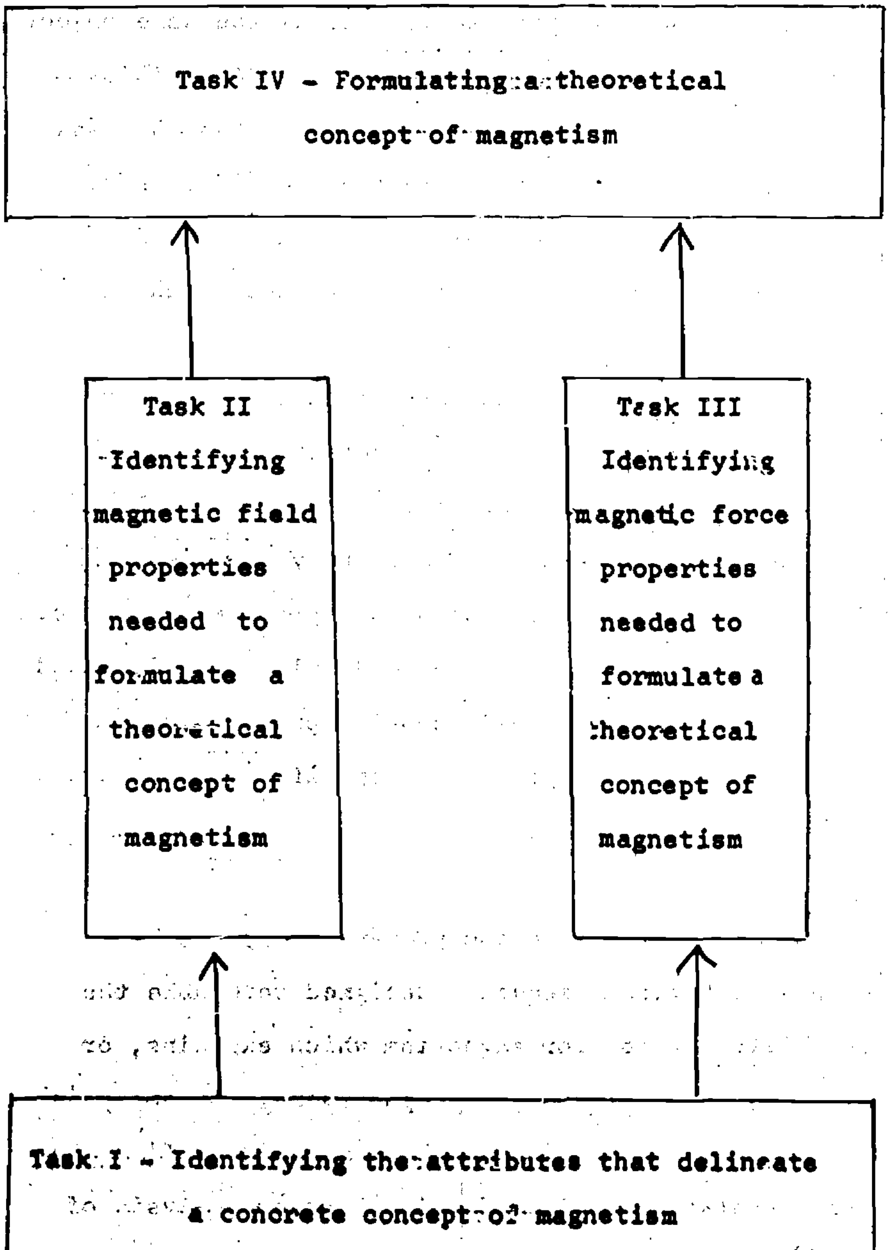

Fig. 1.--Organization of learning tasks in the physics lesson: Magnets and Magnetism.

predicted interrelationships are in accord with the performance objectives identified in Appendix B.

Task I involves the learning of the concept of magnetism at a concrete level which enables the classification of observable phenomena that are related to the properties of magnets. Task IV involves the formulation of an abstract or theoretical concept of magnetism which provides a reasonable "explanation" for the class of phenomena that constitutes Task I. To enable the student to move from the concrete to the theoretical level, tasks II and III provide experiences related to the properties of magnetic fields and magnetic forces, respectively. Task IV requires the abstraction of these macro field and force properties to "explain" the phenomena of magnetism by similar properties on a micro scale.

A hierarchical relationship has been predicted to exist between these major tasks and between the subtasks within them as indicated in Figures 2 and 3. Evidence of positive transfer between these tasks and subtasks would provide support for the existence of such a learning hierarchy. Although the sequence of instruction was in the order given in Appendix A, it should be recalled that Gagné (1968) has suggested that learned intellectual skill will generate positive transfer regardless of the presentation sequence.

Test Instruments

A performance measure was developed for assessing the extent of learning relative to each subordinate competency of the identified performance objectives. This instrument was

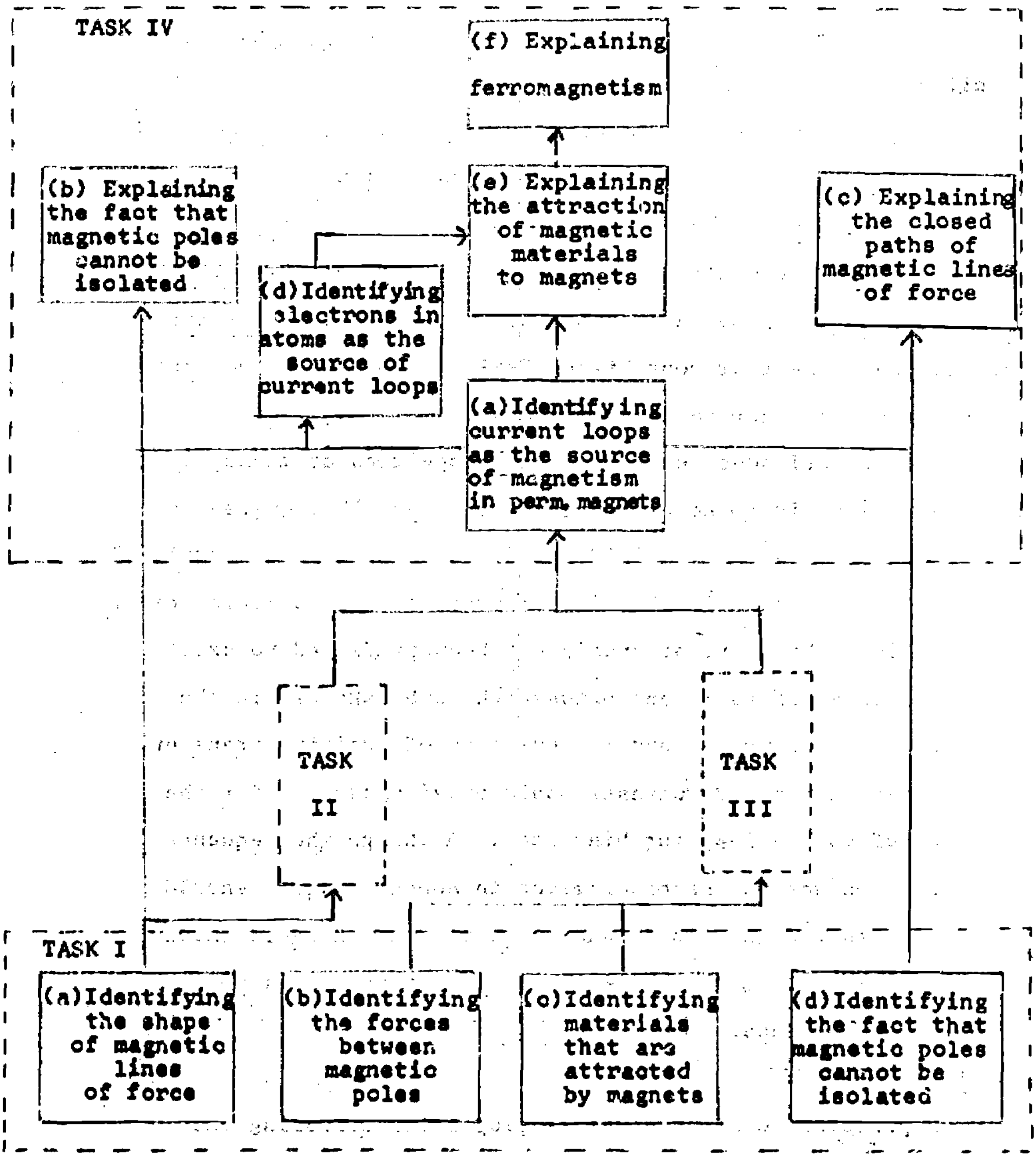

Fig. 2.--Predicted hierarchical relationship among the subtasks of Task I, Tasks II and III, and the subtasks of Task IV.

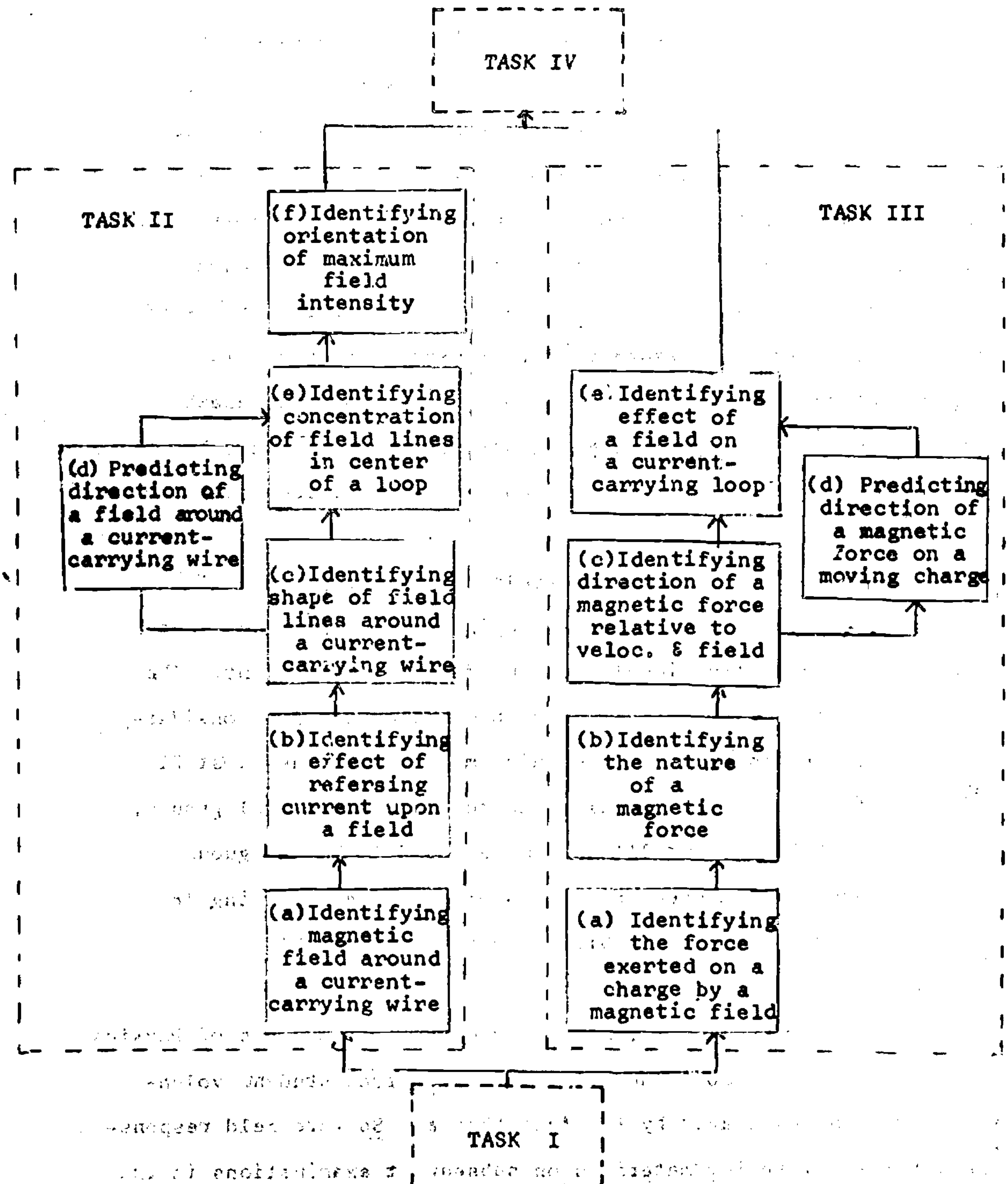

Fig. 3.--Predicted hierarchical relationship among the subtasks of Tasks II and III.

administered as a pretest to the control group and as a posttest to the two treatment groups. Although the posttest data yielded a KR-20 reliability of .65 (k = 21), the use of correlational methods to determine an estimate of reliability was not deemed entirely appropriate, particularly for transfer considerations. Greater dependability in the assessment of learning of each subordinate competency could have been expected from the use of two or more items to measure the attainment of each subtask, but unfortunately this method was not adopted in the present study. In terms of content, the instrument was validated by three physics instructors who judged the items to adequately represent the objectives.

A second instrument was developed for the purpose of ascertaining student attitudes and opinions concerning various aspects of the instructional modes used in the experiment. The primary purpose of collecting this information was for consideration during revision of the learning materials. The first 21 items of the scale were administered to all experimental groups. Three items (15, 16, and 21) that were found to be ambiguous were subsequently deleted prior to scoring. The remaining 18 items yielded an alpha reliability coefficient of .91.

<u>Subjects</u>

Subjects (Ss) were randomly selected from a group of Physics 107 volunteers at FSU. The selection of Ss from student volunteers were necessitated by the fact that all Ss were held responsible for the learning materials on subsequent examinations in the course. Performance data obtained from a midterm examination administered prior to the investigation did not reveal any systematic differences among groups or between Ss and the remainder of the class.

Apparatus

The IBM 1500 Instructional System was used to direct and monitor the activities conducted at each instructional station. The following equipment was installed at each station for the experiment: IBM 1510 Terminal and Kodak Carousel 35mm slide projector. The laboratory stations had the following additional apparatus: DC power supply, copper wire, bar magnets, and a small magnetic compass. All Ss shared one technicolor Super 810 film loop projector with accompanying Sawyer Mira Screen.

Experimental Design

The design of this experiment was similar to the "Posttest-Only Control Group Design" of Campbell and Stanley (1963). The design differed in that a second treatment group was added. Primary interest was focused upon performance differences between the two treatment groups. The control group was included to determine whether either treatment exerted a positive influence upon performance.

Procedure

The experiment was conducted at the FSU-CAI Center immediately prior to instruction of similar material in the conventional course. Timing was critical since Ss were expected to possess requisite entry behaviors but to have received no formal instruction at FSU over material used in the investigation.

The first phase of the experiment involved procurement of Ss. All students enrolled in Section 1 of Physics 107 at FSU during the Fall, 1969-70 Quarter were invited to participate in the experiment. The fifty volunteer Ss were randomly assigned to one of three treatment groups (L, S, or C) as they reported for instruction at the CAI Center. Each instructional session was limited to six students due to constraints imposed by facilities and equipment.

The students assigned to group L (16 Ss) received instruction by the laboratory version of the magnetism lesson. Group S (16 Ss) was instructed by the parallel, simulated laboratory version. The posttest and attitude measure were administered individually to each S in the treatment groups immediately upon completion of the lesson.

Group C (18 Ss) was used as a control to establish baseline entry behaviors. The performance measure was administered individually to these Ss as a pretest followed by instruction via the simulated version of the learning materials. Group C received only the attitude measure following the instruction.

Total instructional time for each S was :ained from the user's file of the computer system. Addition ly, the midterm examination score in Physics 107 was procured for each S from the professor of the course.

Results

The results of the experiment should be considered in light of the identifiable limitations of the data. For the assessment of learning outcomes, Gagné (1967) suggested consideration of the characteristics of distinctiveness and freedom from distortion. Post hoc analysis of the items used in the performance measure indicated their general failure to be distinctive in two respects. Many of the items appeared to fail in distinguishing between the measurement of different intellectual skills and/or between intellectual skills and verbalizable knowledge. In particular, a failure to discriminate between solving ability requiring the use of the right-hand rule and the learning of principles related to current loops has been noted on items 10 and 15. Distortion due to interference and distraction appeared prevalent on items 7, 9, 11, and 14. For example, the word "perpendicular," which received much emphasis in the lesson, attracted a disproportionate number of incorrect choices on items 7 and 14 and the figures used in items 9 and 11 had a seemingly adverse influence upon responses. These factors should be kept in mind while interpreting the results.

Instructional effectiveness. The effectivenss of the two instructional sequences was measured in terms of posttest performance and total instructional time. The results of these measures are shown as means with associated standard deviations in Table 1 along with the mean score of the control group on the same performance measure administered as a pretest. Instructional time was not recorded for control Ss because suitable experimental control could not be exercised over their instruction and no posttest was administered.

TABLE 1.--Means and standard deviations of test performance and total instruction time

Condition	Measure			
	Test Performance		Instructional Time(Min)	
	M	SD	M	SD
Laboratory (L)	11.6	3.3	84.7	12.4
Simulated Laboratory (S)	11.2	2.8	86.3	13.8
Control (C)	5.8*	2.3	**	

* Received the criterion measure as a pretest.
** Time was not recorded.

Since the effectiveness of the laboratory version of the lesson had not been previously established, a t test was made comparing this condition with the control condition. This test for differences between means on the performance measure yielded a t = 6.12 (P <.01). A comparison of posttest performance for the two treatment conditions provided no evidence of the superiority of either laboratory or simulated laboratory as a supplement to CAI instruction. To provide an indication of the effectiveness of the instructional sequence by individual objective, Table 2 contains the proportion of correct responses for each item of the performance measure. Systematic differences between the two treatment groups are not apparent.

The total instructional time required for the laboratory version of the magnetism lesson was compared with the time required for instruction by the simulated laboratory version. Under the conditions of the present experiment, no differences between the mean instructional times for the two versions were revealed by a t test. It should be noted, however, that approximately 15 minutes of proctor time was required to prepare the laboratory condition prior to each administration of the experiment thus saving at least an equivalent amount of student time.

The attitude scale was administered to all Ss in an effort to derive opinions concerning the effectiveness of the experimental conditions. Since there was no way for the Ss to compare the two conditions, the data reflect opinions concerning the CAI presentation mode supplemented with either actual or simulated concrete referents.

TABLE 2.--Proportion correct by item and learning task on the performance measure.

Test Item	Learning Task	Proportion Correct		
		Condition		
		L	S	C
1	Ib	.88	.88	.94
2	Id	.75	.75	.22
3	Ic	.94	.81	1.00
4	Ia	.81	.75	.33
5	IIa	.75	.75	.50
6	IIb	.94	.94	.72
7	IIc	.31	.50	.68
8	IIIa	1.00	.75	.06
9	IId	.19	.38	.28
10	IIe	.56	.50	.17
11	IIId	.31	.31	.06
12	IIIb	.88	.94	.11
13	IIIc	.88	1.00	.06
14	IIIe	.31	.06	.17
15	IIf	.44	.56	.22
16a	IVa	.25	.44	.06
16b	IVd	.38	.44	.06
16c	IVb	.00	.00	.00
16d	IVc	.06	.38	.00
16d	IVe	.44	.25	.06
16f	IVf	.19	.19	.06

TABLE 3.--Means and standard deviations of an attitude measure concerning CAI instruction supplemented with concrete referents

Condition	Attitude Measure	
	M*	SD
Laboratory (L)	60.8	13.3
Simulated Laboratory (S)	62.3	8.8
Control (C)	69.1	7.1

* A value of 54 would represent a neutral attitude.

A total score of 54 based upon three points per item would reflect a neutral attitude toward the instructional sequence. On this basis, 42 Ss displayed a positive reaction to the sequence compared to eight negative reactions. There was general agreement that the simple experiments (3.96)* and slides (4.04) were facilitating in the learning experience and that there is a definite need for the development of more lessons of this type (3.92). Most of the students emphatically agreed that the lesson was a welcome change of pace from usual classroom experiment in the future (4.04).

Learning transfer. Evidence for the existence of positive transfer among learning tasks should emerge from the pass-fail pattern between adjacent relevant tasks and subtasks. Accordingly, success with a higher task following success with a lower task (++) or failure to succeed with a higher task after failing with a lower task (--) would constitute evidence in support of positive transfer. Success with a higher task following failure with a lower task (+-) would be in contradiction of theories of positive transfer. Higher failure following lower success (-+) would provide no transfer data but would indicate points at which the program becomes ineffective for particular learners. Since the instructional sequences were identical and since no evidence was found to suggest that the posttest scores for the two treatment groups were from different populations, the data for these two groups were combined for the investigation of transfer effects.

* Denotes mean score on the associated test item.

The performance patterns for predicted hierarchical relationships between higher-level and relevant lower-level tasks and subtasks are shown in Table 4. The upper part of the table shows patterns relating the subtasks within task IV to tasks II and III and to relevant subtasks within task I. (Since several items in tasks II and III were judged to be suffering from distortion effects and lack of distinctiveness, success was arbitrarily defined to be 4 passes out of 6 for task II and 3 out of 5 for task III.) The lower part of the table displays a breakdown of transfer patterns within tasks II and III.

The final column indicates the proportion of instances consistent with the predicted hierarchy of tasks and subtasks. The evidence for the existence of such a hierarchy would have to be considered far from conclusive on the basis of the present study. However, it is not possible to differentiate between instances of deviation from the hierarchy and instances of dubious data resulting from an undependable performance measurement. Correct response resulting from guessing on the multiple choice items would tend to bias the proportions downward due to a disproportionate increase in columns (3) and (4). Due to the conservative manner in which the free response items were scored, these items were rescored giving Ss the "benefit of the doubt" and the proportions in the upper part of the table were recalculated. The new proportions were found to be approximately .10 greater than those reported in Table 4.

TABLE 4.--Pass-fail patterns of achievement between adjacent lower and higher level relevant learning tasks, and proportion of instances consistent with predicted positive transfer.

Transfer to task or subtask	Frequency of pass-fail pattern-Higher, Lower (1) ++	(2) --	(3) +-	(4) -+	Total testable frequency (1) + (2) + (3)	Proportion instances consistent with positive transfer $\frac{(1) + (2)}{(1) + (2) + (3)}$
II from Ia	13	5	2	12	20	.90
III from Ib,c	20	1	6	5	27	.78
IVa from II,III	5	13	6	8	24	.75
IVc from Id,IVa	9	17	4	2	30	.87
IVd from IIa	3	16	5	8	24	.79
IVe from Ib,c, IVa,d	0	21	9	2	30	.70
IVf from IVe	4	21	2	5	27	.93
IIa from Ia	21	4	3	4	28	.89
IIb from IIa	22	0	8	2	30	.73
IIc from IIb	12	1	1	18	14	.93
IId from IIc	4	14	5	9	23	.78
IIe from IIc,d	3	14	14	1	31	.55
IIf from IIe	12	11	4	5	27	.85
IIIa from Ib,c	24	1	4	3	29	.86
IIIb from IIIa	25	0	4	3	29	.86
IIIc from IIIb	27	0	3	2	30	.90
IIId from IIIc	10	2	0	20	12	1.00
IIIe from IIIc,d	4	20	2	6	26	.92

In an effort to determine the credibility of the predicted hierarchy relative to other conceivable hierarchies, a table of conditional probabilities for all possible response patterns was computed. The probability of mastering task X_2 given that task X_1 has been mastered should indicate the degree to which predictable relationships obtain among the various tasks. Since no hierarchy was identified that appeared more reasonable than the predicted hierarchy, these results have been presented in an order similar to Table 4. Table 5 contains conditional probabilities related to the major tasks and to subtasks within tasks I and IV calculated with the data obtained from rescoring the measure of Task IV performance. Table 6 includes conditional probabilities of success within tasks II and III. Asterisks identify success probabilities pertaining to the predicted hierarchy.

TABLE 5.--Probability of responding correctly to the test item corresponding to task X_2 given that task X_1 is mastered.

X_2 / X_1	$P(X_2X_1)$										
	Ia	Ib	Ic	Id	II	III	IVa	IVc	IVd	IVe	IVf
Ia		.88	.84	.80	.52*	.88	.72	.44	.40	.56	.32
Ib	.79		.66	.75	.50	.79*	.68	.46	.39	.54*	.32
Ic	.75	.86		.75	.50	.82*	.68	.46	.46	.50*	.36
Id	.83	.88	.88		.50	.83	.79	.58*	.50	.58	.42
II	.87*	.93	.93	.80		.87	.80*	.47	.40	.67	.47
III	.85	.85*	.89*	.77	.50		.73*	.50	.42	.54	.31
IVa	.86	.90	.90	.90	.57*	.90		.67*	.62*	.76*	.48
IVc	.79	.93	.93	1.00*	.50	.93	1.00*		.64	.71	.50
IVd	.77	.85	1.00	.92	.46	.85	1.00*	.69			.54
IVc	.86	.94*	.86	.86	.63	.86	1.00*	.62	.69*		.62*
IVf	.80	.90	1.00	1.00	.70	.80	1.00	.70	.70	1.00*	

* Indicates predicted transfer.

TABLE 6.--Probability of responding correctly to the test item corresponding to task X_2 given that task X_1 is mastered

X_1 \ X_2	Ia	IIa	IIb	IIc	IId	IIe	IIf	Ib	Ic	IIIa	IIIb	IIIc	IIId	IIIe
	P(X_2 X_1)													
Ia		.84*	.92	.40	.36	.48	.56							
IIa	.88*		.92*	.38	.38	.54	.54							
IIb	.77	.73*		.40*	.30	.53	.53							
IIc	.77	.69	.92*		.31*	.46*	.38							
IId	1.00	1.00	1.00	.44*		.67*	.78							
IIe	.71	.76	.94	.35*	.35*		.71*							
IIf	.88	.81	1.00	.31	.44	.75*								
Ib									.96	.86*	.89	.93	.29	.18
Ic								.86		.89*	.89	.93	.36	.21
IIIa								.86*	.89*		.89*	.93	.29	.18
IIIb								.86	.86	.86*		.93*	.31	.14
IIIc								.87	.87	.87	.90*		.33*	.20*
IVd								.80	1.00	.80	.90	1.00*		.40*
IIIe								.83	1.00	.83	.67	1.00*	.67*	

* Indicates predicted transfer.

Tables 5 and 6 contain probabilities which represent the degree to which success with a given task or subtask can be predicted from success on another task or subtask. Since meaningful probabilities are predicted when task X_1 precedes task X_2, the most significant information regarding adjacent tasks is found above the diagonal. However, since in a perfect hierarchy all values below the diagonal would be 1.00, the extent to which these values deviate from 1.00 gives an indication of the degree to which the hierarchy approaches the ideal. Again, the results are inconclusive because of the dependability of the data.

Discussion

Based upon the theoretical position that the simulated environment mode would facilitate concept and principle learning in science in a manner similar to that of laboratory experiences, the present pilot study investigated the relative effectiveness of the two instructional modes. Additionally, an attempt was made to identify evidence of positive transfer between learning tasks for the purpose of sequencing the tasks during further revisions of the learning materials.

No evidence was obtained to suggest that simulated laboratory experiences are any less effective than the performance of simple experiments in providing concrete referents to aid in the learning of abstract concepts and principles. The results appear to suggest the merit of continued attempts to design appropriate laboratory simulations, particularly when limitations can be identified for actual laboratory manipulations. Some of the laboratory limitations that would tend to enhance the feasibility of simulation would include health hazards, excessive costs, constraints imposed by overcrowding, and unavailability of appropriate experiments.

The possible differences in student time required for instruction were deliberately negated in the present study because of the limited availability of the CAI system. The decision to set up the laboratory apparatus in advance was made to ensure adequate time for all Ss to complete the instructional sequence. If total instructional time were redefined to include proctor time for preparation of the laboratory condition, the results would tend to favor the simulated environment mode. However, since experience seems to indicate that laboratory time is a function of the specific experiment of interest, any attempt to generalize with respect to time differences would entail considerable risk and probably should not be attempted.

Student opinion tended to favor the use of concrete referents in association with CAI over other instructional methods. The general consensus that the lesson was a welcome change of pace from usual classroom activities is of particular interest. This expression appears to suggest continued investigation of potential innovative uses of various media forms to promote greater student interest.

Due to apparent distortion and a lack of distinctiveness in the test items, the results were generally inconclusive with respect to positive transfer throughout the predicted learning hierarchy. While the existence of the predicted hierarchy could not be substantiated, neither could it be refuted. Enough scattered bits of evidence were revealed, however, to warrant resequencing of the lesson and investigating for indications of positive transfer with a more appropriate criterion measure. Extreme care should be exercised in restating the objectives and in devising the performance measure in an effort to differentiate between various intellectual skills and between intellectual skills and verbalizable knowledge.

Verifcation of the predicted hierarchy could conceivably shed light upon Novak's (1969) suggested "taxonomy of conceptual levels." The hierarchy in question identifies three possible levels of theoretical concept development. Task I could be considered an identification or classification stage where attributes of the concept are delineated. Tasks II and III appear to constitute a developmental stage where concrete referents are used to provide experiences that are congruent with the theoretical concept to be abstracted. The final stage might be referred to as a formulation stage where the learner builds a "mental model" which subsumes the concrete concept along the analogous concrete referents. The formulation of theoretical concepts appears to require some undefined intellectual skill related to the process of abstraction through the use of analogies.

The attempt to substantiate the existence of a learning hierarchy generated more questions than answers. Some of the questions which appear to be deserving of further investigation include the following:

(1) What is the evidence related to the existence of hierarchies of verbalizable knowledge?

(2) To what extent can intellectual skills be differentiated from verbalizable knowledge? Can skills be identified that are "content-free"? These questions have implications for the formulation of process goals in education.

(3) What is the evidence that would tend to support the existence of a taxonomy of conceptual levels?

(4) Can the process of formulating abstract concepts be differentiated from principle learning and rule-using?

(5) What is the appropriate role of subsuming processes in a learning hierarchy?

The answers to these questions would prove invaluable in the design and sequencing of science instruction.

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APPENDIX A

ANALYSIS OF LEARNING TASKS IN THE LESSON:

MAGNETS AND MAGNETISM

1. Observing the effect of a magnetic field upon magnetic materials.

2. Observing the effect of bringing like and unlike magnetic poles together.

3. Observing the effect of breaking a bar magnet into smaller pieces upon the magnetic poles.

4. Mapping magnetic field lines and observing their shape.

5. Observing the existence of a magnetic field created by an electric current flowing through a wire.

6. Observing the relationship between the direction of current flow and the direction of the magnetic field created by the current.

7. Observing the shape of magnetic lines of force created by a current-carrying wire.

8. Observing the effect of an external magnetic field upon a current-carrying wire.

9. Predicting the direction of the magnetic lines of force around a current-carrying wire with the aid of the first right-hand rule.

10. Observing the direction of the magnetic lines of force around a current-carrying wire loop.

11. Predicting the direction of a magnetic force with the aid of the second right-hand rule.

12. Observing the nature of the force exerted by a magnetic field upon a moving charge.

13. Observing the relationship between the directions of current flow and external magnetic field, and the direction of a magnetic force.

14. Predicting the behavior of a current loop placed in a magnetic field.

15. Observing that a magnetic force has maximum intensity when the magnetic field is perpendicular to the direction of current-flow.

16. Considering the existence of current loops in magnetic materials to explain observable magnetic phenomena.

17. Considering the existence of current loops with magnetic poles at the molecular level as an explanation of the inability to isolate magnetic poles.

18. Considering the existence of magnetic lines of force which form closed paths at the molecular, current-loop level as an explanation for the closed paths of magnetic field lines observed for magnetic materials.

19. Considering the motion of electrons in atoms and molecules as a possible source of current loops in magnetic materials.

20. Considering the orientation of current loops comprised of unpaired electrons as a source of magnetism in magnetic materials.

21. Considereing the existence of molecular forces that tend to prevent disorientation of current loops in ferromagnetic materials after an external magnetic field has been removed.

APPENDIX B

TERMINAL OBJECTIVES

I. The student will be able to identify the phenomena which a model for magnetism would need to explain. These phenomena which characterize magnetism and which differentiate properties of magnets from properties of charges are:

a. Magnetic lines of force form closed paths but electric lines of force begin and end on the charges. (4)*

b. Magnetic poles and charges are similar; in both cases like repel and unlike attract. (1)

c. Some materials are attracted to magnets but others are not. (3)

d. Magnetic poles differ from charges in that poles cannot be isolated while charges can. (2)

II. The student will be able to identify the magnetic field properties upon which a model for magnetism can be built. These field properties which are associated with a current-carrying wire are:

a. Current flowing through a wire sets up a magnetic field around a wire. (5)

b. The direction of the magnetic field around a wire is reversed when the direction of the current is reversed. (6)

c. Magnetic lines of force form concentric circles around a current-carrying wire. (7)

d. The direction of the lines of force around a current-carrying wire as predicted with the aid of the first right-hand rule. (9)

e. Coiling a current-carrying wire into a loop will concentrate the lines of force at the center of the loop. (10)

f. The maximum magnetic field intensity around a current-carrying wire loop is perpendicular to the loop at its center. (15)

III. The student will be able to identify the magnetic force properties upon which a model for magnetism can be built. These force properties which are associated with a magnetic field are:

a. A magnetic field exerts a force on a moving charge. (8)

b. Magnetic forces are only deflecting in nature and do no work upon a charge. (12)

* Indicates test item constructed to assess attainment of this objective.

c. The magnetic force exerted on a charged particle is perpendicular to the directions of both the velocity and the magnetic field. (13)

d. The direction of the deflecting force exerted on a current-carrying wire by a magnetic field as predicted with the aid of the second right-hand rule. (11)

e. The orientation of a current-carrying wire loop in a magnetic field. (14)

IV. The student will be able to utilize a theoretical model for magnetism to explain the phenomena which characterize magnetism. The phenomena which will be explained by the student are:

a. The source of magnetism in a permanent magnet. (16a)

b. Magnetic poles cannot be isolated. (16c)

c. Magnetic lines of force form closed paths. (16d)

d. The source of current loops in magnetic materials. (16b)

e. Some materials are attracted to magnets and others are not. (16e)

f. Some materials can be permanently magnetized. (16f)

APPENDIX C

MAGNETS AND MAGNETISM

CRITERION TEST

MAGNETS AND MAGNETISM

CRITERION TEST

Select the best answer to each of the following items and mark it on the answer sheet.

1. Which of the following statements is correct?

   1) Like magnetic poles attract - unlike repel; like charges repel - unlike attract.

   2) Like magnetic poles repel - unlike attract; like charges attract - unlike repel.

   3) Magnetic poles and charges are similar; in both cases like attract - unlike repel.

   4) Magnetic poles and charges are similar; in both cases like repel - unlike attract.

2. Which of these statements is correct?

   1) Electric charges can be separated but magnetic poles cannot.

   2) No isolated electric charges or magnetic poles have ever been observed.

   3) A magnet can be cut into two pieces, a north pole and a south pole, but electric charges cannot be separated.

   4) Magnets can be separated into north and south poles, and electric charges can be separated into positive and negative charges.

3. Identify the true statement.

   1) All metals are attracted to magnets.

   2) Iron and similar metals are attracted to magnets but copper and aluminum are not.

   3) Glass and common plastics are attracted to magnets.

   4) Ferromagnetic materials are not suitable for permanent magnets.

4. Lines of force in a magnetic field differ from those in an electric field in that

   1) they form closed curves.

   2) they do not give the direction of the force.

   3) they terminate on the magnetic poles.

   4) there is an infinite number of them.

5. When an electric current flows through a wire

   1) an electric field is set up in the space around the wire.

   2) a magnetic field is set up in the space around the wire.

   3) the space around the wire is not influenced unless the direction of current flow is alternating.

   4) the space around the wire is not influenced under any circumstances.

6. Changing the current flow in a wire to the opposite direction will

   1) eliminate any field that was previously present around the wire.

   2) increase the magnitude of any field around the wire.

   3) reverse the direction of any field around the wire.

   4) have no influence on the space around the wire.

7. The magnetic lines of force associated with a long, straight current-carrying wire

   1) are parallel to the wire.

   2) are perpendicular to the wire.

   3) form concentric circles around the wire.

   4) spread out radially with the wire at the center.

8. A constant magnetic field exerts forces on

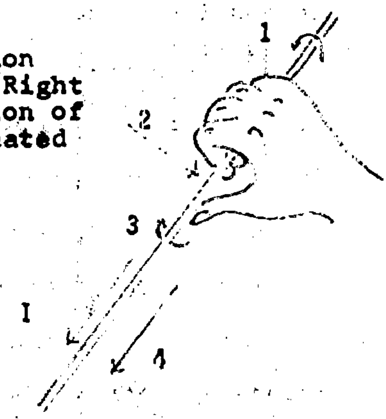
   1) stationary charges.

   2) moving charges.

   3) both stationary and moving charges.

   4) neither stationary nor moving charges.

9. With current flowing in the direction indicated by I in the drawing, the Right Hand Rule tells us that the direction of the lines of force will be as indicated by the arrow at



1) 1

2) 2

3) 3

4) 4

10. If the wire above were coiled into a loop, the lines of force would

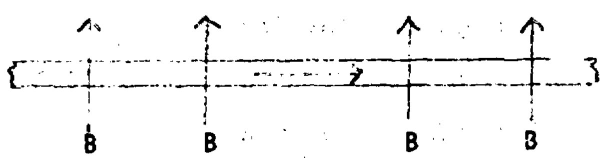
1) cancel each other out.

2) be in the direction of the current, I, at all points.

3) no longer be described by the Right Hand Rule.

4) be concentrated inside the loop.

11. The following diagram represents a section of straight, current-carrying wire placed in a magnetic field:



The wire will be deflected

1) toward the top of the paper.

2) to the right.

3) into the paper.

4) out of the paper.

12. The force exerted upon a charge by a magnetic field

1) is a pure deflecting force that does no work upon the charge.

2) may slow down the charge.

3) increases the total energy of the moving charge.

4) is sometimes called a fictitious force.

13. When a charged particle moves with a velocity, v, through a magnetic field, B, in a direction perpendicular to the field, the magnetic force on the particle is in

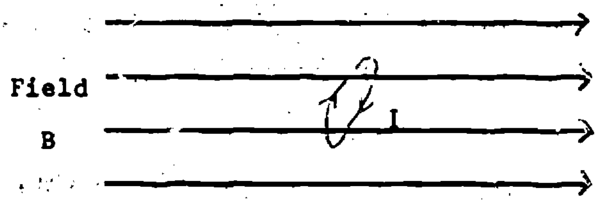
    1) the direction of v; perpendicular to B.

    2) the direction of B; perpendicular to v.

    3) a direction perpendicular to both v and B.

    4) a direction that is not perpendicular to either v or B.

14. The figure below represents a current loop placed in a magnetic field with the direction of the current in the loop as indicated by the arrows on the loop. Assume that the plane of the loop is perpendicular to the plane of this sheet of paper.



The loop will tend to

    1) move in the direction of the field.

    2) move in a direction perpendicular to the field.

    3) rotate in a clock-wise direction.

    4) rotate in a counter-clockwise direction.

15. The maximum intensity of a magnetic field set up by a current loop is

    1) perpendicular to the loop at its center.

    2) in the plane of the loop directed toward its center.

    3) dependent upon the direction of the current in the loop.

    4) in the direction of the current in the loop.

16. We have developed a simple model for magnetism in this lesson. Use this model to account for each of the following: (Keep your explanation brief.)

a) The source of magnetism in a permanent magnet.

b) The fact that magnetic poles cannot be isolated.

c) The fact that magnetic lines of force form closed loops.

d) The source of current loops in magnetic materials.

e) The fact that some materials are attracted to magnets and others are not.

f) The fact that some materials are ferromagnetic (can be permanently magnetized).

APPENDIX D

NAME ______________________ STUDENT NUMBER ______________________

This is not a test of information; therefore, there is no one "right" answer to a question. We are interested in your opinion on each of the statements below. Your opinions will be strictly confidential. Do not hesitate to put down exactly how you feel about each item. We are seeking information, not compliments; please be frank.

1. Instruction such as this is one of the most effective ways to learn new concepts.

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

2. There is a definite need for the development of more lessons of this type.

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

3. I would rather learn the material some other way.

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

4. I would have learned more from a lecture.

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

5. I would choose CAI instruction rather than participate in a group discussion on the topic.

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

6. I learn more from this type of instruction than from studying on my own.

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

7. As a change of pace from usual classroom activities the CAI lesson was welcome.

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

8. Such instruction does not provide the necessary motivation to learn the subject.

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

9. In view of the amount of time involved, I feel too little was accomplished.

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

10. This is not a very efficient way to learn.

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

11. My liking for this type of instruction outweighs my disliking.

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

12. I would volunteer to participate in an experiment like this again if I had the opportunity.

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

13. I would like to receive instruction of this type for an entire course sometime.

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

14. I feel that I learned enough from this lesson that it will not be necessary for me to attend the lecture over this same material.

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

15. This method of instruction could be effective but was not appropriate for this lesson.

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

16. This method of instruction could be effective but this particular lesson was poorly developed.

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

17. The simple experiments made this lesson more interesting.

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

18. The simple experiments made it easier to learn the concepts presented in this lesson.

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

19. The film loops added very little to the lesson.

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

20. The slides were more of a distraction than an aid to learning.

1	2	3	4	5
Strongly Disagree	Diagree	Uncertain	Agree	Strongly Agree

21. The CAI system would be just as effective for this type of learning without any additional visual aids.

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

The next 4 questions are to be answered by those who received instruction by the simulation version of the lesson.

22. The simulation of experiments is a poor substitute for the "real thing."

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

23. I feel that I could learn more through the actual manipulation of the apparatus.

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

24. Simulation of experiments has possibilities, but the ones in this lesson were not realistic..

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

25. The quality of the simulations should be improved.

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

The next 4 questions are to be answered by those who received instruction by the laboratory version of the lesson.

26. I feel that the manipulation of the apparatus increased my understanding of the physics concepts.

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

27. Setting up the simple experiments was more bother than it was worth.

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

28. I had difficulty trying to figure out how to set up the apparatus.

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

29. I think that movies or simulation of the experiments would be just as effective as a learning aid.

1	2	3	4	5
Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree

30. The best part of this lesson was

31. The best way to improve this lesson would be to

32. I would like to make the following additional comments.

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