Scientific Notation in Instructional Design

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The vocabulary of instructional design is varied, sometimes vague and often personally interpretive.

For example, let's look at the titles of different kinds of teaching models. Do you suppose we could arrive at agreement as to how these models differ?

1. Group Investigation Model
2. The Jurisprudence Model
3. Social Inquiry Model
4. The 7-Group Model
5. Study-of-Thinking Model
6. An Inductive Model
7. Inquiry Training Model
8. Development Model
9. A Model for Creativity
10. Classroom Meeting Model

Many of us could arrive at a general agreement, but what happens to that agreement when we design the instructional strategies? And, is there any way to scientifically compare or differentiate these models with one another? The nonspecific nature of these titles is representative of the methods by which they are identified.

One of the attempts to quantify this instructional process has been the development of the so-called *system approach*. Figure 1 illustrates the system approach.

As system designers who write and teach these kinds of things, we often stress the component relationship and omit the decisions required in the application of the principles of learning. That is, skills such as writing objectives or conducting formative evaluation or constructing a learning hierarchy are skills readily learned. But skills involved with the design of instructional strategies demand a working knowledge

The system approach is the compartmentalization of differentiated functions whereby each component of the task incorporates the operationalized characteristics of input-process-output variables. It is also synergetic and cybernetic in nature. Here is a typical system model.

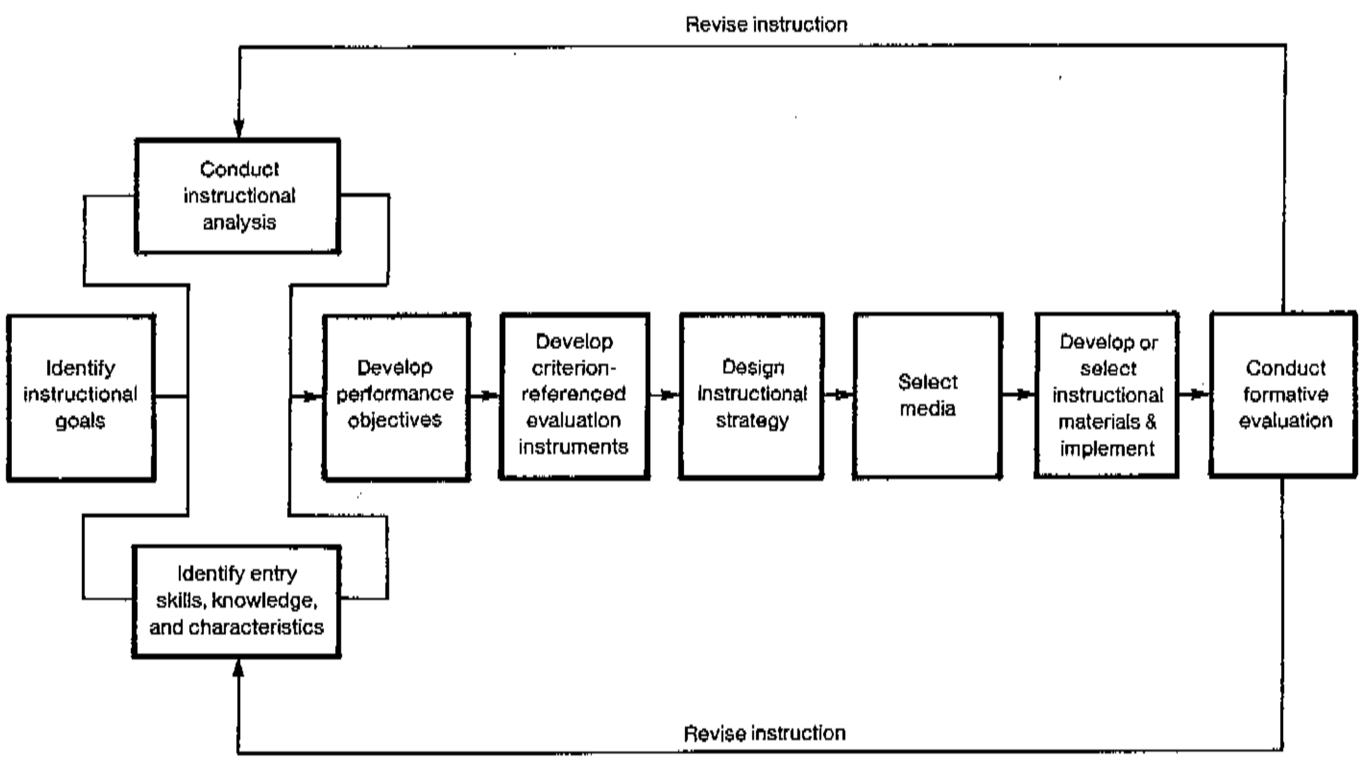


Figure 1. A definition of the system approach. (From *The Systematic Design of Instruction* by W. Dick and L. Carey, 1978. Copyright 1978 by Scott, Foresman and Company. Reprinted by permission.)

of psychological constructs and their appropriate application for a predictable domain of learning.

Teachers often learn this skill after years of practice through trial and error. Even after they have developed highly successful skills, the information is not published or shared with other teachers and designers because there is no common language that eliminates ambiguity of idiosyncratic methods.

Instructional design flowcharts which depict the interrelations of major activities in the design of instruction have served designers well but in a limited way.

First, most system models had their genesis in computer or hardware technology, which may inadvertently have lessened the social aspects of instruction (that is, the incidental attitudinal outcomes which always accompany instruction).

Second, most system models were originated to facilitate the design and production of instructional materials. Therefore, many system models do not address the larger systems to which development of materials is a central, but small part. The larger systems include staff training, administration, management, and diffusion and instructor roles as shown in Figure 2.

Third, material development flowcharts act as procedural guide posts in material development, but they rarely reach the point of specificity whereby they help the designer in making student prescriptive decisions. Student prescriptive decisions are those decisions where the designer combines the principles of learning (arousal theory, reinforcement theory) to levels of learning (cognitive, affective, psychomotor) for a specific target population (age, IQ), with individual constraints unique to that group (large class, urban-rural setting). For example: How would you differentiate the teaching or design of instruction, if you wanted the students to exhibit problem solving behaviors, concept learning behaviors, memory behaviors, motor skills behaviors, or even attitude change behaviors? I am sure you can define these behaviors, but where are the instructional strategies to bring about those kinds of changes in student learned behaviors?

Where are the models that help us make those decisions? Where is the notation and the language system that will allow us to compare one instructional approach to another approach? This question leads into the major thrust of this paper; scientific notation of the instructional designer's decision is possible and currently in practice. It provides a means of noting the form and substance of the interaction between the instruction and the student.

In the early 1970's Dr. David Merrill at Brigham Young University began to operationalize the instructional design process with the encouragement and support of research by his staff and graduate students. The task was an exciting one, and very soon other persons recognized the potential impact of such an analysis and operationalized approach, and they joined with Dave Merrill.

They recognized that once the instructional design process was quantified through a notation system, communication between scientist and designer would be possible. For one of the first times, a clear, unambiguous, parsimonious statement could be written which in fact reflected the designers' decisions in designing instructional strategies.

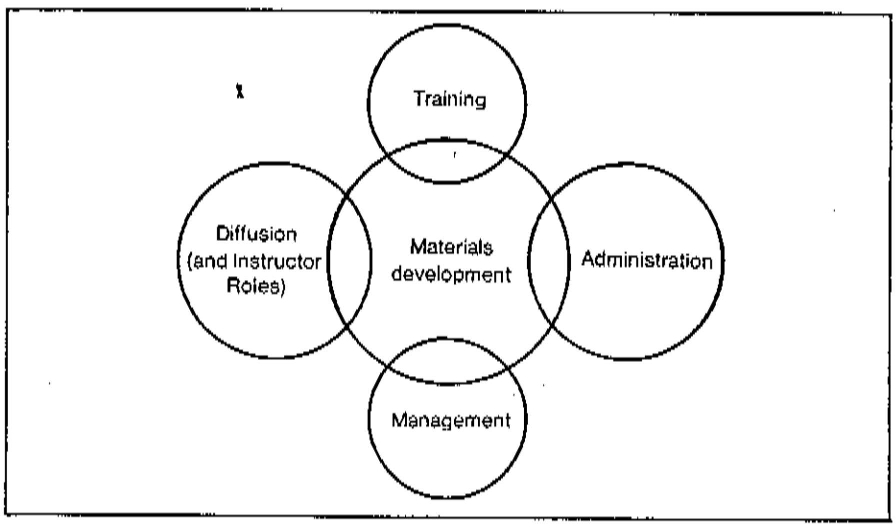


Figure 2. The expanded scope of the system approach.

Here is a nonexample of scientific notation, probably seen by most of us, in this description of a teacher in the classroom. The teacher:

- Calls the class to attention,
- Informs the learner of the goal for the day's activities,
- Presents materials,
- Provides guidance, and
- Evaluates student responses.

There may be many instructional supervisors who might rate that teacher high because so many of the right things were present (for example, attention, stating objective, guidance, and evaluation).

Here is another nonexample of scientific notation in instructional modules. They also have a system, but with little specific rationale vis-a-vis strategies. Once the objectives are stated the strategy falls into the cycle of:

- Presentation of information,
- Practice with information, and
- Evaluation of learner response.

In both examples, the process embedded in such strategies as informs learner, presents information, provides guidance, practice with information, becomes lost because of the ambiguity. The teacher/designer wrestles with defining the interactions and manipulations of content and presentation for the purpose of obtaining predictable learner outcomes.

From the instructional designer's position there are two fundamental questions. (1) What is to be taught? (2) How is it to be taught?

Question number one is often influenced by persons other than the designer (for example, school boards, curriculum committees). Therefore, the notation system developed by Merrill and others concerns itself with "How something is taught," that is, the science of instruction—the principles of instruction as opposed to the principles of learning.

The principles of instruction operationalize the cause-effect relationship between learning theory and learner outcomes. The application of the operationalized principles of instruction may be viewed as the technology of instruction. Technology develops ways of using the principles. Before describing the notation system let's place the value of this process in perspective. That is, where in the major classes of instructional variables is this notation system having impact?

The Merrill/Boutwell notation system speaks directly to the organizational strategies (Figure 3) variables and operationalizes the cause-effect relationship between learning theory and learner outcomes.

Functional notations:

E = Expository (telling)
I = Inquisitory (asking)
G = Generality
eg = example } Instances
$\overline{eg}$ = nonexample } Instances
al = algorithms
[ai] = attribute isolation

These seven functions define the relationship between content (what is being taught) and presentation (how it is being taught).

Fundamentally, each display originates from the simple two-by-two factorial shown in Figure 4. Any particular instance of a complex cognitive instructional presentation must always feature some combination of presentation mode and content mode. There are many combinations of possible displays, especially when mathemagenic information is included. The next paragraph provides an example of the notation system discussed.

Imagine a junior high school teacher preparing a science unit dealing with factors affecting the weather. The teacher's objective is to have the students reach the classification level of learning. To reach the classification (concept) level, the students must be tested with unencountered instances of the concept (that is, novel to the student.) The appropriate selection of the teacher design strategy can be seen in the following set of symbols. This list of symbols will, in a very limited space, convey more meaning and accuracy with less ambiguity than pages of prose. The teacher's strategy for concept learning follows.

Concept: EG, XEG, 3d ↑ Eeg, E [eg]
Ieg/$\overline{eg}$m, (−Eeg/$\overline{eg}$m),
Δ d ↑ m

This lesson strategy describes a concept treatment that consists of the following display elements.

1. EG—an expository presentation of the definition.
2. XEG—an expanded generality which further defines the concept, perhaps with a paraphrase or metaphor.
3. 3d ↑ Eeg—a series of three divergent exemplars arranged in ascending dif-

1. *Conditions* that cannot be manipulated by the designer, but must be reckoned with since they do interact with methods.
2. *Methods*, under certain conditions, the designer manipulates these strategies to achieve a specific outcome.
3. *Outcomes*, evaluation of methods under different conditions.

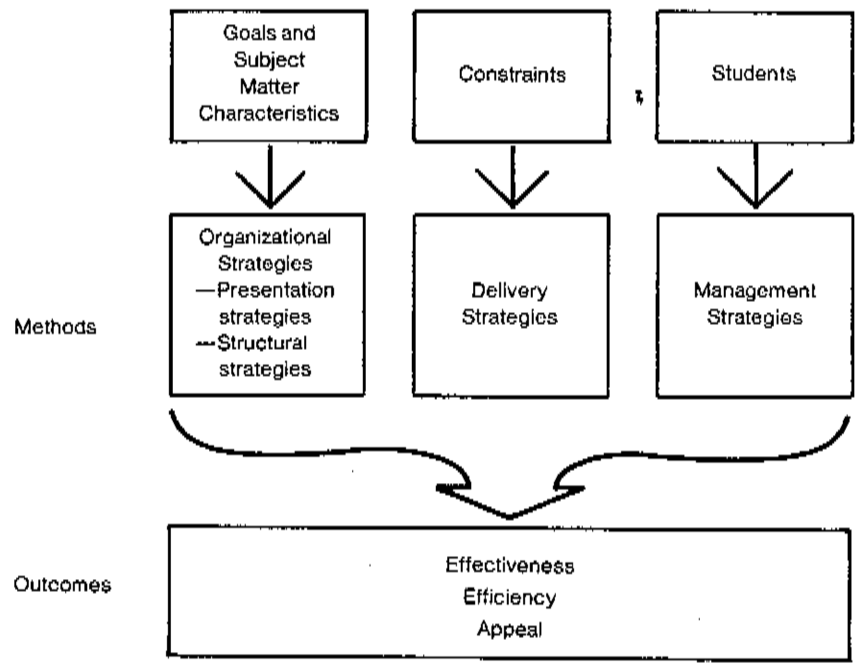


Figure 3. A model showing the major classes of instructional variables and the major interrelationships among those classes. (From "A Knowledge Base for Improving our Methods of Instruction" by C. M. Reigeluth and M. D. Merrill. *Educational Psychologist*, in press. Reprinted by permission of the authors.)

		Presentation Mode	
		E	I
Content Mode	G	EG	IG
	eg	Eeg	Ieg

Possible Displays

(EG) Expository generality
(Eeg) Expository instance
(IG) Inquisitory generality
(Ieg) Inquisitory instance

Figure 4. The origin of displays.

Here are the definitions of *generality, example,* and *nonexample.*

G = Generality, rules, concepts

Generalities are used to present the specific information to be learned in that unit of instruction. They are brief and if fully understood by the student, the objective should be met.

- What type of content is usually included in generalization? Generalities contain at least one of the following:
  (1) A list or statement of what is to be memorized,
  (2) A definition of the concept,
  (3) A statement of the principle,
  (4) A listing of the steps in performing a psychomotor behavior.
- What is the purpose of generality elaborations?
  Generality elaborations are used to further explain the generality. They are necessary for students who do not fully understand the generality or terms therein.
- What type of content is usually included in generality elaborations?
  Generality elaborations can contain:
  (1) A restatement of the generality;
  (2) An analogy, algorithm, or mnemonic;
  (3) A rationale for the generality.

eg = examples

Examples are instances of a concept and the application of a procedure or a principle; all examples of generalities contain all the critical attributes necessary for class membership.

$\overline{eg}$ = nonexample

In a nonexample, one or more of the critical attributes is missing.

There are other functions in the total process, but they tend to embellish rather than define the relationship. Those other functions are:

1. Mathemagenic information—additional or augmented information provided to facilitate learning. Examples would be an expanded generality, cues, and prompts.
2. Quantitative functions
   A. Sequence
      (1) Order, which display comes first
      (2) Sequence, what is the pattern of the display
      (3) Simultaneous versus sequential display
   B. Quantity
      (1) Number (how many displays)
      (2) Ratio (what displays in what proportions)

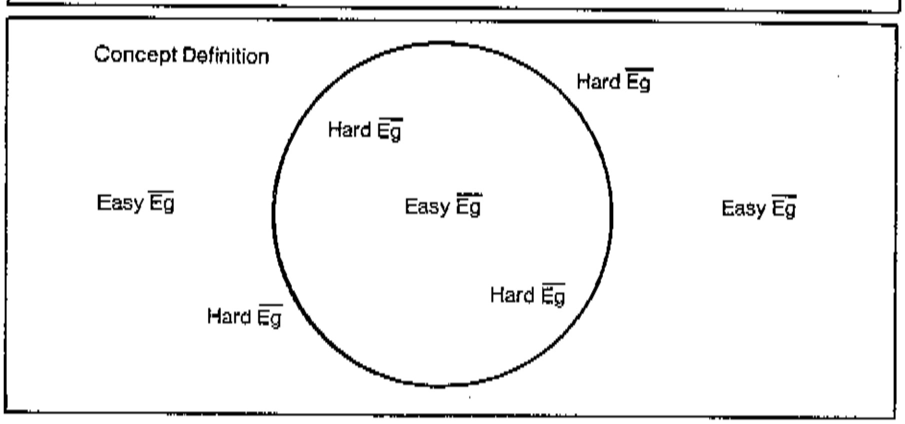


Figure 5. Instance difficulty.

ficulty order using the expository mode.

4. E [eg] —followed by an expository exemplar which has each critical attribute isolated.
5. Ieg/$\overline{eg}$m—the fifth display will provide an opportunity for the student to identify (inquisitory I) which of a matched (m) exemplar (eg) nonexemplar (eg) pair is a member of a concept class.
6. (–Eeg/$\overline{eg}$m)—if an incorrect choice (– . . .) is made another display will present a prompted ( ) expository comparison of match exemplar-nonexemplar pair as feedback.
7. Δd ↑ m—the delta (Δ) indicates that the student has the option to try as many choices as seems necessary. Each successive matched (m) exemplar and nonexemplar pair will be matched to each other but be divergent (d) from the previous pair and in ascending order of difficulty.

This explanation and example of an instructional design notation system will encourage (1) parsimonious specification of the instructional treatment, (2) ready comparison between competing treatments, and (3) suggested research directions for unresolved treatment ideas for the best instructional sequence. For a good introduction into these variables, see Merrill and Boutwell (1973) and, for a more detailed explanation, see Reigeluth and Merrill (in press).

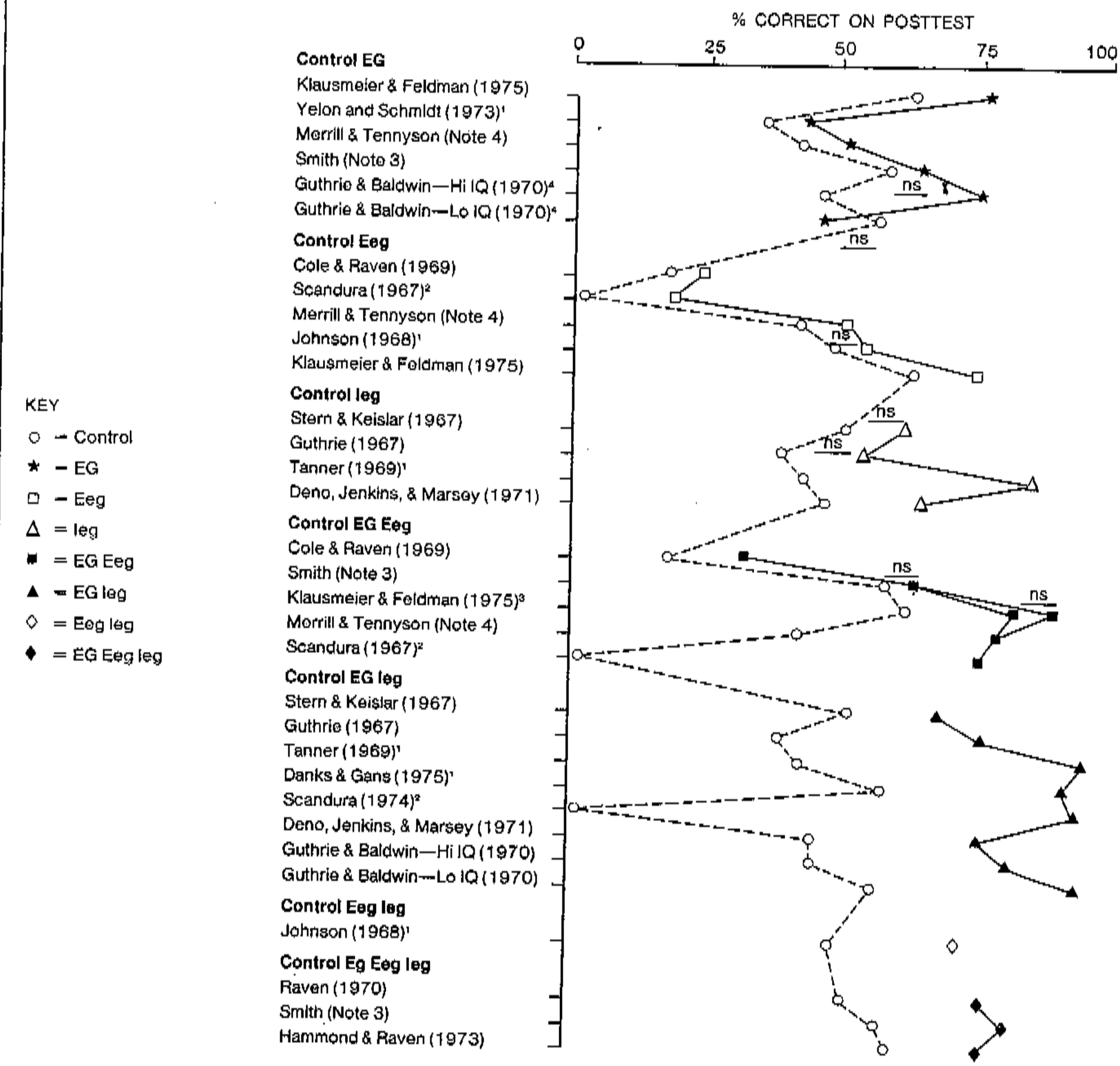
There are three other range variables (that is, on a continuum) that can influence the relationship between displays.

1. Scope
   a. of a generality; for example, rule vs. concept definition
   b. of an instance; for example, example or nonexample
2. Attribute matching of instances
   a. matched—irrelevant attributes similar (example/example or nonexample/nonexample)
   b. paired—irrelevant attributes not similar (example/nonexample)
3. Instance difficulty (See Figure 5.)
   a. easy—all relevant attributes obvious
   b. hard—all relevant attributes ambiguous

Figure 6 demonstrates the research applicability of the notation system. The two sheets of Figure 6 represent a review of research completed by David Merrill (1976). Using the variables listed in the notation system as his guide, Merrill reviewed and compared research studies which demonstrated the superiority of one instructional variable over another. For example, the first comparison is between a control group (0) and an expanded generality (EG) and was reported by Klausmeier and Feldman (1975). (This study and all of the research studies listed in Figure 6 are listed in full in Merrill, 1976.)

Conclusion

The future of the systems approach to instruction is assured because of its proved effectiveness and efficiency. The adoption of a notation system that is generalizable to all instructional designers will allow and encourage a common communication base. Once a designer decides to use the notation system, the display sequences will probably be a heuristic approach (trial and error). As the more successful sequences become apparent they will become established



NOTES:

Unless dictated by ns, all vertical differences are statistically significant.

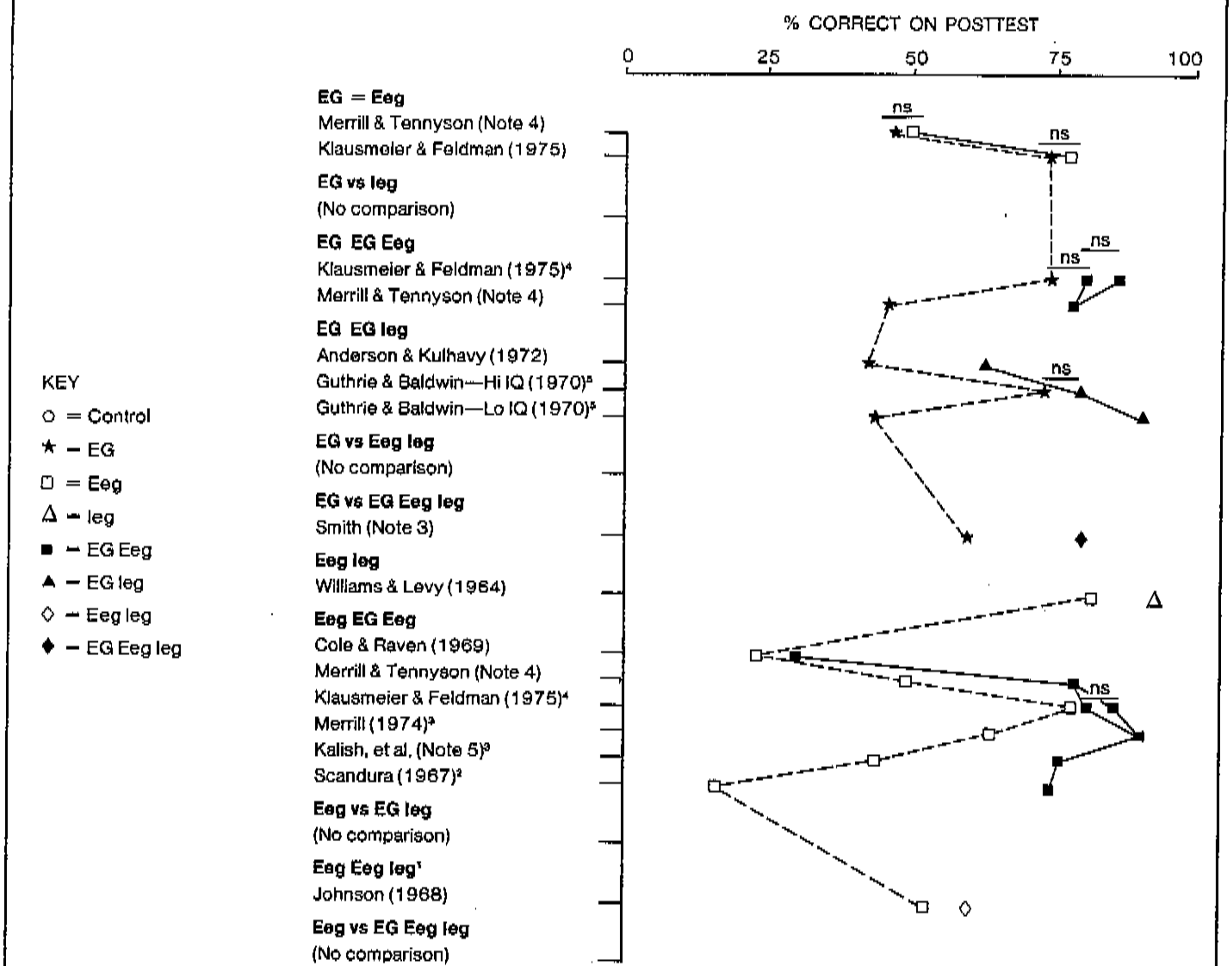
[1]When the % correct could not be determined, raw scores were plotted relative to each other but arbitrarily positioned on the coordinate axis.

[2]% of students correctly solving all posttest problems.

[3]Klausmeier and Feldman had 2 EG Eeg groups. One group had 3 times as many eg's as the other.

[4]Number of practice problems used by the student to reach criteria is plotted here.

Figure 6. Comparisons of primary presentation forms with control groups (sheet 1 of 2). (From *Technical Report No. 3* by M. D. Merrill, 1976. Copyright 1976 by Courseware, Inc. Reprinted by permission.)



NOTES:

Unless indicated by ns, all vertical differences are statistically significant.

[1]When the % correct could not be determined, raw scores were plotted relative to each other but arbitrarily positioned on the coordinate axis.

[2]% of students correctly solving all posttest problems.

[3]Several dependent variables were used. The number of examples used by the student to reach criteria is plotted here.

[4]Klausmeier and Feldman had 2 EG Eeg groups. One group had 3 times as many eg's as the other.

[5]Number of practice problems used by the student to reach criteria is plotted here.

Figure 6. Comparisons of primary presentation forms with control groups (sheet 2 of 2). (From *Technical Report No. 3* by M. D. Merrill, 1976. Copyright 1976 by Courseware, Inc. Reprinted by permission.)

instructional display rules for future use. These strategy rules can then be expanded to varying target populations for strategy adaptions. The outcome might be a proven set of instructional strategy displays for each domain of learning for specific target populations. The implications are enormous.

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