DOCUMENT RESUME

ED 374 131 TM 021 596

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TITLE Instructional Analogies and the Learning of Concepts.
PUB DATE Apr 94
NOTE 12p.; Paper presented at the Annual Meeting of the American Educational Research Association (New Orleans, LA, April 4-8, 1994). For a related paper, see ED 335 000.
PUB TYPE Reports - Res[illegible]/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *College Students; *Comprehension; *Concept Formation; Higher Education; Instructional Materials; *Learning; Performance; Physiology; Statistical Analysis; *Student Attitudes; Teaching Methods; *Training
IDENTIFIERS *Analogies

ABSTRACT

This paper describes two studies designed to examine the effect of instructional analogy training on the level of comprehension of 10 advanced physiological concepts. In the first study, 161 college students received instruction either with or without analogies. Levels of student performances were compared across three conditions: (1) concept lessons only, including definitions and examples for each concept; (2) similar concept lessons, but with an analogy included for each concept; and (3) analogy concept lessons with additional prompts guiding analogy use. In the second study, immediate and delayed comprehension of 94 college students was compared between groups receiving concept lessons with and without analogies. Results showed significantly higher scores of comprehension, both immediately and after the delayed period, for those students who had received the analogies. Moreover, students receiving analogies reported higher levels of perceived lesson enjoyment. Results are discussed in terms of the prescriptive use of analogies within instructional materials and future research possibilities. Two graphs compare performances. (Contains 75 references.) (Author/SLD)

INSTRUCTIONAL ANALOGIES AND THE LEARNING OF CONCEPTS

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This paper describes two studies which were designed to examine the effect of instructional analogy training on the level of comprehension of ten advanced physiological concepts. In the first study, 161 college students received instruction either with or without analogies. Levels of student performances were compared across three conditions: (a) concept lessons only (including definitions and examples for each concept), (b) similar concept lessons but with an analogy included for each concept, and (c) analogy concept lessons with additional prompts guiding analogy use. In the second study, immediate and delayed comprehension of 94 college students was compared between groups receiving concept lessons with and without analogies. Results showed significantly higher scores of comprehension, both immediately and after the delayed period, for those students who had received the analogies. Moreover, students receiving analogies reported higher levels of perceived lesson enjoyment. Results are discussed in terms of the prescriptive use of analogies within instructional materials and future research possibilities.

An instructional analogy has been defined as an explicit, nonliteral comparison between two objects, or sets of objects, that describes their structural, functional, and/or causal similarities (Stepich & Newby, 1988). As an example, it can be said that: "A red blood cell is like a truck in that they both transport essential supplies from one place to another through a system of passageways."

Commonly utilized as instructional tools (e.g., Curtis & Reigeluth, 1984; Glynn, 1989), analogies have been employed to teach a variety of subjects including mathematics (Novick & Holyoak, 1991), science (e.g., Andrews, 1987; Bean, 1990; Cavese, 1976; Dupin & Johsua, 1989; Last, 1985; Scheintaub, 1987), business policy (Peattie, 1990), reading comprehension (Hammadou, 1990), composition (Ledger, 1977), computer programming (Rumelhart & Norman, 1981), and problem solving (Gordon, 1961). In a particularly innovative application, Nichter and Nichter (1986) taught rural villagers in India principles of health and nutrition by likening them to the more familiar principles of planting and tending crops. The purpose of analogies is to allow relational information to be mapped from a source known to the learner onto one that is unknown (Vosniadou & Schommer, 1988).

Instructional analogies have been shown to consist of four basic components: (a) the target domain (or subject), (b) the base domain (or analog), (c) the connector, and (d) the ground (Gentner & Gentner, 1983; Stepich & Newby, 1988). The target domain refers to the information to be learned. In the previous example, the target domain is the red blood cell. The base domain (truck, in the example) consists of information familiar to the learner which will be used to make a comparison. The connector is a verb phrase, such as is like, which establishes the nature of the relationship between the base and target domains (Rumelhart & Norman, 1981). Finally, the ground is a detailed description of the similarities, and possible differences, indicated by the connector. In the example, the ground is represented by the phrase, "transport essential supplies from one place to another through a system of passageways."

Theories of analogical transfer have been developed to explain how information from a base domain is used to facilitate the understanding or manipulation of information in an unrelated target area (Gentner, 1982, 1983, 1988; Gentner & Jeziorski, 1990; Gentner & Toupin, 1986; Holyoak, 1984, 1985; Holyoak & Thagard, 1989; Thagard, Holyoak, Nelson, & Gochfeld, 1990). In most cases, analogical transfer is viewed as a process of "second order modeling" (Holyoak, 1985) in which a model of the base domain is used to progressively develop a model for the target domain. This process takes place through the mapping of a limited set of properties between base and target domains. Mapping is viewed as a two part process which includes first, finding something in memory to use as a base domain and second, determining which properties or characteristics of the selected base domain to map onto the target. Central to this conceptualization is the idea that prior knowledge, organized and stored in the learner's memory, serves as a framework or "simulative context" for the acquisition of new knowledge (Glass & Holyoak, 1986; Mayer, 1979).

Although analogies have been frequently utilized and have become integral parts of accepted theories of instructional design (e.g., Reigeluth & Stein, 1983), research to this point has been divided in terms of their effectiveness in enhancing the comprehension

and retention of concepts. Drugge and Kass (1978), for example, found that verbal analogies did not significantly increase immediate comprehension, whereas Radford (1989) found significant differences in achievement on immediate recall using verbal analogies in biology. Gabel and Sherwood (1980), in a year-long study of analogies within a high school chemistry curriculum, demonstrated no significant improvement in chemistry achievement. Likewise, Bean, Singer, and Cowen (1985) found that analogies were not effective with above average students. In contrast, Vosniadou and Ortony (1983) found that subjects given verbal analogies recalled more factual information from a scientific passage. Issing (1990) reached a similar conclusion in a study using physics materials. Gilbert (1989) reported no gains in achievement using analogies in science texts. Hayes and Henk (1986) found that the use of analogies resulted in improved performance on a knot tying task. Reed (1987) found that his subjects, given an analogous practice problem, were better able to solve algebra word problems, and Vosniadou and Schommer (1989) found improved recall for information in expository texts.

Due to these inconsistent findings, the limitations of analogies and their parameters for effective learning should be investigated in order to successfully predict when analogy use might be beneficial within a particular instructional setting. To date, a number of factors limiting the effectiveness of analogies have been identified (e.g., Duit, 1991; Thagard, 1992). The first, and most prominent, is the learner's comprehension of the analogy used to teach the new content. In the Gabel and Sherwood study (1980), analogies were not helpful to all students. However, it was shown that as many as 48% of the subjects did not fully understand the analogies used to teach the content. Of those that did understand, scores on the semester achievement test were significantly higher. Similar results were found in later studies designed to identify difficulties in chemistry problem solving (Gabel & Samuel, 1986; Gabel & Sherwood, 1984), and with physics materials (Issing, 1990). Such findings have prompted some investigators to suggest the need for teachers to devote time and effort to explain the relationship between the analog and the target and to explicitly delineate relevant similarities and differences (e.g., Clement, 1993).

A second limitation of analogies is the tendency to overgeneralize or create unwanted misconceptions. This occurs when attributes of the analog are included or mapped to the target when the attributes, in fact, are not relevant or do not exist. Spiro, Feltovich, Coulson, and Anderson (1989) describe the occurrence of overgeneralization in a study with college students who were using analogies to understand biological phenomenon. Many students overextended the analogies by making inferences that led to scientifically incorrect explanations. In a different study, students receiving analogies from base domains significantly different from the target domains proved to be more successful than students receiving analogies derived from similar or near-base domains (Halpern, Hanson, & Riefer, 1990). The authors' conclusions suggested that analogies from far domains required deeper levels of processing to successfully complete the structural mapping and thus this extra effort increased students' abilities and subsequent performances. Another interpretation, however, is that analogies from near base-domains may have more readily generated misconceptions which led to unshared attributes being treated as valid. This is similar to the findings by Shustack and Anderson (1979), for example, when they asked subjects to read and recall brief biographies of fictional characters. When asked to identify statements they had seen before, subjects showed a higher frequency of false recognitions (i.e., overextensions) when the fictional biography was closely analogous to the life of an actual famous person.

Another limiting factor appears to be the time required to make use of analogies. Analogies may be effective, but not efficient, as instructional aids. In two sets of studies, Simons (1982, 1984) noted that including an analogy in printed instructional materials increased recall and comprehension of new information, but only under conditions of unlimited study time. Restricting the amount of time that subjects were given to read the materials reduced the advantage of the analogy-based instruction. According to Simons (1982, 1984), analogy-based materials require more time because the additional information in the analogy must be read and then compared to other information in the text. This additional effort pays off in subsequent reading of the same materials, however. Learners can often reread text with analogies more rapidly than text without analogies because of the deeper conceptual understanding they gained from the first reading (Simons, 1984).

A final limiting factor is the learners' need for cues, or prompts, indicating the relationship between the new information and its base domain. Cueing is particularly important because learners do not always see the relationship between the base and target domains. As a result, they do not always use the base when performing the target task (Gick & Holyoak, 1980, 1983; Glynn, 1991). Reed, Dempster, and Ettinger (1985) tried a variety of cueing techniques to increase the transfer of information between algebra word problems. These included: describing the relevancy of the analog, making the analog solution available while solving the target problem, explaining why a particular

equation was used to solve an analog problem, and matching the complexity of analog and target problems. The failure to produce consistent results demonstrated the difficulty learners have in applying analogous information, even when its usefulness is highlighted.

As indicated by the previous studies, the emphasis in the study of analogies and their impact on learning has been on the analogy itself (i.e., how it is constructed, cued, and placed within the instructional materials). Davidson (1979) has described analogies as a way of translating abstract information into a form that is more concrete and imaginable and, therefore, more easily understood. According to Simons (1982, 1984) this is the analogy's "concretizing" function.

This concretizing function was demonstrated in a lesson designed by Iona (1982) to teach college students about electricity. The more abstract components of an electrical system were likened to the more concrete and familiar components of a hydraulic system in which water flows from a hilltop reservoir to a mill at the bottom of the hill. In this comprehensive analogy, electrical voltage was likened to the distance between the reservoir and mill; amperage was compared to the rate of water flow; and electrical resistance was likened to narrow pipes or other factors that might obstruct the flow of water. Other concretizing applications can be found in subjects as diverse as biology (e.g., Cavese, 1976; Radford, 1989) and political science (Russell, 1980).

For this investigation, two studies were designed to further define when, under what conditions, and for how long instructional analogies are effective. In the first study, levels of student performances on learning unfamiliar physiology concepts were compared across three conditions: (a) those receiving concept lessons only (including definitions and examples for each concept), (b) those receiving similar concept lessons but with an analogy included for each concept, and (c) those receiving the analogy lessons with additional prompts guiding analogy use. In the second study, immediate and delayed recall were compared between groups receiving concept lessons with and without analogies. To date, little empirical data exists regarding the long term retention effects facilitated by analogy-based instruction. Additionally, learners' levels of perceived confidence and lesson enjoyment were measured and compared across the analogy and no analogy conditions.

The relevant questions addressed by these studies include:

- Does the use of analogies, within a concept learning task, increase learner performance compared to lessons without analogies?
- Do learners who receive prompts, suggesting the recall and use of presented analogies, perform better than learners who receive analogies without prompts and those who receive instruction without analogies?
- Does an intervening period of time between training and comprehension testing impact learner performance?
- Do individuals receiving instruction with analogies indicate increased levels of confidence in their abilities to recall the concepts and/or increased levels of lesson enjoyment?

Study 1

Methodology

Participants

One hundred sixty one students (125 females and 36 males) from an undergraduate educational psychology course at a large midwestern university participated in the initial study. All students selected this option for meeting a course requirement for participation in research. Students' ages ranged from 18 to 35 years (M = 20.29; SD = 2.05). Most students were either sophomores (61%) or juniors (33%), with only one freshman, seven seniors, and two graduate students participating. The majority of students declared education (65%) as their chosen field of study with the remaining declaring humanities, science, or physical education.

Instructional Materials

Concept selection. Physiology was selected as the content area for this study due to its concept-rich nature. Additionally, this subject matter was predicted to be highly unfamiliar to the target group of students. A physiology instructor from the School of Veterinary Science and Medicine and two graduate assistants served as content experts for the development of the materials.

The content experts used their course textbook, *Physiology: A Regulatory Systems Approach* (Strand, 1983), to identify 611 potential target concepts. This list was reduced to 32 using the following criteria: (a) concepts that labeled structures were eliminated while concepts that labeled processes were retained, (b) two word concepts were eliminated while one word concepts were retained, (c) concepts common in everyday language were eliminated (e.g., salivation, respiration). Ten concepts (ossification, parturition, micturition, adaptation, peristalsis, disinhibition, pinocytosis, adsorption, summation, and catabolism) comprised the final selection for the study.

Instructional materials development. The purpose of the development phase was to create the lesson—in no-analogy, analogy, and analogy with prompts versions—that would be used to teach the selected concepts. In its final form, each lesson included the following written materials: (a) an introduction and instructions, (b) instructional materials covering each of the 10 concepts including a

definition, a one-paragraph description of the physiological process, and a verbal analogy (for the analogy and analogy with prompts conditions), and (c) a posttest (including prompts within the analogy with prompts conditions only).

The first step in creating the lesson was to meet with the content experts and construct an analogy for each of the selected concepts. Construction of the analogies followed the steps outlined by Stepich and Newby (1988). For each concept, the feature most important to comprehension was identified and one or more concrete items having the same or similar features were listed. One of these concrete items, likely to be familiar to the learners, was then chosen as the base domain. The analogy was completed by describing the similarities between the chosen base and the concept. As an illustrative example, the feature most important to understanding the process of peristalsis is the progressive wave of muscular contractions propelling food through the digestive tract. Potential base domains included extracting toothpaste from a tube or squeezing ketchup out of a single-serving packet. Both bases were expected to be familiar to the learners and the ketchup squeezing analog was chosen as the more accurate of the two. Peristalsis was then described in terms of the analog:

> *"Peristalsis is like squeezing ketchup out of a single-serving packet. You squeeze the packet near one corner and run your fingers along the length of the packet toward an opening at the other corner. When you do this, you push the ketchup through the packet, in one direction, ahead of your fingers until it comes out of the opening."*

This process was repeated for each of the other nine concepts. Each of the base domains was selected based on two criteria: (a) it was highly familiar to the learners (Gabel & Samuel, 1986) and (b) it was from a different, or far, domain than the to-be-learned concepts (Halpern, et al., 1990).

Next, several physiological textbooks (Holmes, 1979; Jacob & Francone, 1985; Luciano, Vanden, & Sherman, 1983; Parker, 1984; Schmidt & Thews, 1983; Strand, 1983; Vanden, Sherman, & Luciano, 1983) were used as information sources and an initial draft of the lesson was written. This draft included an introduction to the study, and a definition, description, and analogy for each concept. This version was then evaluated by the content experts and two experienced instructional designers to ensure its accuracy, clarity, and appropriateness for the intended students. Suggestions obtained were incorporated into a second draft of the materials. The instructional materials were again evaluated by the content experts and their suggestions were incorporated into a third draft.

At this point the content experts wrote a set of 20 multiple-choice test items (two items per concept). Each item was developed to focus on concept application as opposed to simple recall. All test items were then randomly ordered. The test directions and items were then reviewed by an instructional designer and experienced teacher who had not seen the materials previously and who was not a content expert. This helped to ensure that the tests were clear and comprehensible. Evaluative comments were incorporated into a revised version of the test. The same test versions were given to all groups; however, for the analogy group with prompts, one line prompts were inserted next to each of the test questions. The prompts simply stated, "Remember the analogy and use it to help you complete the answer to this question." References to individual analogies were not included in the prompts.

Material development was followed by a field test involving 24 students. Each student was given a complete set of materials, including an introduction, a set of instructional materials, and a posttest. The instructional materials and tests differed depending on the treatment conditions (no analogy, analogy, and analogy with prompts). Reliability scores, using the Kuder-Richardson formula (Mehrens & Lehman, 1984), indicated a posttest reliability of .68. Based on the suggestions given by the participants, the wording of several questions was revised and a brief introduction to the study was incorporated within the written materials.

Procedures

For the formal investigation, students were allowed to sign up for one of five 90-minute periods. Each session was scheduled in a university classroom that could accommodate up to 50 students. Two investigators monitored each experimental session following a given set of instructions. After the students were seated one investigator briefly introduced the study and distributed the instructional materials containing the introduction and concept lessons. These materials were collated, alternating between the three types of lessons. The copies were distributed by rows, thus achieving a randomized assignment to the three treatment conditions. Following this procedure, 54 students were assigned to both the analogy and no analogy groups whereas 53 students comprised the analogy with prompts group.

Students were allowed to study the materials for as long as they wished. As each person completed the concept lesson, the instructional materials were returned to the investigator. Based on the code number on each instructional packet, a matching posttest was given to the student. Again, all posttests were identical except that the analogy with prompts group received statements suggesting recall of the analogy to facilitate answering. There was no limit on the amount of time available to finish the exam. As students finished their posttest they

returned it to the investigator and were allowed to leave. If students desired further information about the study they were debriefed by the second investigator in an adjoining room and then thanked for their participation.

Results and Discussion

A one-way analysis of variance conducted on the posttest results indicated a significant difference between the responses of the three groups of students (F (2, 158) = 5.35; MS_B = 78.2; p = .006). As illustrated in Figure 1, multiple group comparisons using the Scheffé F demonstrated significant differences (F_S = 4.56, $p < .05$) between responses of the analogy with prompts (M = 14.57; SD = 3.88) and the no analogy groups (M = 12.33, SD = 3.88) and between the analogy (M = 14.24; SD = 3.72) and the no analogy groups (F_S = 3.36; $p < .05$). No significant differences were found between the analogy and the analogy with prompts conditions. Additional analyses for differences across gender and class within each of the treatment groups showed no significant differences in test scores based on those variables.

These results indicate, first and foremost, that the use of analogies may significantly improve learners' comprehension of concepts. When given a posttest requiring the application of new concepts, individuals who had received instructional lessons which included analogies answered more questions correctly than individuals who had not received analogies. This is similar to the findings of Webb (1985) and others, and supports Jonassen's contention (1994) that analogies are "the single most powerful instructional strategy one can use."

Additionally, it is important to note that, unlike other studies in which analogies were used as a strategy to facilitate simple concept recall (similar to a mnemonic memory aid), the posttest questions in this study required the correct application of the new concept. This is a more realistic test of concept knowledge and appears to have been successfully facilitated by the use of analogies in this study.

Finally, these results indicate that although a slightly higher mean score was reported for those receiving the prompts to use the analogies, their results were not significantly different from individuals who received the analogies but were not prompted. Contrary to Gick and Holyoak's (1980, 1983) suggestion of the need for such prompts and cues, their use did not appear to be warranted in this setting. One possible explanation for this result may be due to the timing of the first posttest. All of the students in this study were asked to apply the newly learned concepts immediately after the completion of the instructional materials (which included the analogies). Thus, the relevance of the analogies, together with the definitions and examples, may have been readily apparent to both analogy groups. In this case, both groups were ready and prepared to use the analogies, possibly diminishing or masking the impact of the prompts. Future research is needed to determine the effectiveness of the use of prompts when a longer delay period transpires between initial analogy presentation and final test application.

Another possible reason for the lack of prompt effectiveness in this study could have been due to the prompt itself. The same phrase ("Remember the analogy and use it to help you answer this question.") was presented repeatedly with every posttest question and may have provided little, if any, informational or motivational value. Thus, the prompts may have been ignored, resulting in little, if any, positive benefit. In contrast, a prompt that might have included critical, relevant information for those taking the posttest (e.g., "Remember that peristalsis is similar to ketchup being squeezed out of a single serving package") may very well have garnered attention and resulted in more accurate concept application.

Overall, the results of this first study indicate that analogies significantly impact the learning and application of physiology concepts. Additionally, the use of prompts to remind learners to recall and use the previously presented analogies did not significantly improve test performance.

Study 2

Based on the information from the first study, the second investigation was designed to compare the effectiveness of analogies on comprehension after an intervening time period. In addition, data were desired regarding potential differences in levels of confidence and overall lesson enjoyment between individuals receiving instructional analogies and those who did not.

Methodology

Participants.

In the second investigation, 94 students (70 female, 24 male) from a similar undergraduate educational psychology course, at the same midwestern university as those of the first study, were solicited to participate; however, students from the original investigation were not allowed to participate. Again, students selected this option in order to meet a course requirement for participation in a research study. The participants' declared major fields of study included education (65%), humanities (15%), science (12%), and physical education (3%). Eight participants (six female and two male) failed to return for the follow-up testing; six were from the no-analogy group and two from the analogy group.

Instructional materials

The instructional materials used during this study were based on those used in the first investigation. Similar materials included: (a) the introduction with instructions, (b) the instructional materials covering each of the same 10 physiology concepts (both with

and without the analogies), and (c) the posttest. Because of the previous findings of no significant difference between those receiving the analogies with prompts and those receiving analogies without prompts, posttest prompts were eliminated from this study. Adaptations to the original materials included the creation of a second posttest to be used as a long term retention measure. This delayed posttest was constructed by reordering the original test questions and their possible multiple choice responses. A follow-up questionnaire was also developed to be administered immediately after the first posttest. This questionnaire was designed to obtain demographic information (e.g., sex, age, academic major), as well as estimates of how many questions on the 20-item test students judged they had answered correctly. In addition, a Likert-type item was included to determine learners' degree of perceived enjoyment from the lesson.

Procedures

For this investigation, students were given the opportunity to sign up for one of three 90-minute experimental sessions. As in the first study, all sessions were held in a university classroom and two investigators were present to administer the materials and monitor each session. The investigators used the same randomizing procedures of the first investigation to distribute the instructional lessons. In this case, students were randomly divided into two groups [those receiving analogies ($n = 47$) and those not receiving analogies ($n = 47$)]. After completion of the instructional materials, each student returned the materials and received a posttest. Posttests were identical for all participants. Again, no time limits were imposed for either the completion of the instructional materials or the test. Students were asked to put an identifying code number on their tests (the last 4 digits of their social security number) to allow the investigators to match the students' two tests with the questionnaire responses.

After the tests were completed, students returned them to the investigator and were given a follow-up questionnaire. Upon completion and return of the questionnaire, each student was reminded to return in 14 days to the same location and at the same time. No further instructions were given and students were allowed to leave.

When the students returned two weeks later, they were given the delayed posttest. This test consisted of a short set of directions and the same 20 questions (in a new random order) from the initial posttest. Students were also asked to record their four-digit code number on these tests. No time limit was imposed; tests were returned to the investigator upon completion. As students completed the test they were escorted to an adjoining room and debriefed about the investigation. Two students from the analogy group and six students from the no-analogy group did not return for this 14 day delayed posttest.

Results and Discussion

Study 2 examined three dependent variables: comprehension of new concepts (both immediate and long term), enjoyment of the lesson, and confidence in having mastered the new concepts. In each case, separate analyses were completed.

To compare students' comprehension of concepts across conditions, scores on the 20-question immediate and 14-day delayed posttests were compared based on the method of instruction. A two-factor repeated measures analysis of variance was performed on the number of items answered correctly by each treatment group across both posttests. As shown in Figure 2, those students receiving instruction with analogies attained an average immediate posttest score of 12.94 ($SD = 3.89$) and a 14-day posttest score of 12.31 ($SD = 4.06$). In contrast, the average immediate posttest score of the no-analogy group was 10.53 ($SD = 3.26$) compared to their 14-day score of 9.81 ($SD = 3.44$). Results from the repeated measures analysis of variance indicated that the analogy group significantly outperformed those who did not receive analogies [$F(1, 84) = 19.8$; $MS = 286.38$; $p < .001$]. Moreover, the two groups showed no significant differences between the manner in which they responded during their initial and their 14-day delayed tests. No significant interaction was noted between the groups and the tests.

Similar to Study 1, these results indicate that analogies had a beneficial effect on the comprehension of unfamiliar concepts. That is, students who received instruction which included analogies scored significantly higher on the immediate posttest than those who did not receive the analogies. Moreover, this difference in comprehension was sustained over a 14-day time period. Even though the learners were not prompted to recall or use the analogies in any way, comprehension scores indicate that a difference between the two groups remained even after the 14-day interval. The use of analogies appears to be an effective instructional strategy for increasing learners' immediate comprehension of concepts and facilitating the retention of this knowledge over a two week period of time. Another interesting aspect is that although average scores decreased in both groups from initial to follow-up testing, significant decreases were not noted.

The level of perceived lesson enjoyment (i.e., how well the participants liked the instructional lessons) was measured by a single survey item in which the students were asked to rate their enjoyment of the lesson on a scale of 1 (not at all) to 5 (a lot). A significant difference was found between the analogy ($M = 3.02$) and the no analogy ($M = 2.59$) conditions using a two-tailed t-test ($t(92) = 1.87$; $p<.05$). One possible explanation for these

differences is based on the type of analogies used. The selection criteria utilized within this study required that the presented analogies be familiar, concrete, and easily perceived. As discussed by Duit (1991), analogies provide a degree of imagination and have been hypothesized to link thought with feeling (Gowin cited in Duit, 1991). When faced with learning a totally foreign concept, the presence of something concrete, familiar, and easily understood may have increased learners' overall comfort and subsequent enjoyment of the learning experience (Keller & Kopp, 1987).

With an increased level of enjoyment, one might also expect learners to demonstrate an increased level of confidence for mastering this new content. However, a significant group difference in perceived levels of confidence for successful test performance was not found. On the follow-up survey, confidence in learning was measured by asking the students to predict how many items (of a possible 20) they had answered correctly on the posttest. Means of predicted correct responses for the analogy and no-analogy conditions were 14.19 and 13.55, respectively. A two-tailed t-test indicated no significant difference between the groups' predictions. This finding may have been due to the timing, as well as the level of difficulty, of the posttest (average posttest score was less than 13 of 20; 67%). The survey was completed immediately after the posttest, at which point students in both groups would be likely to recall approximately how many questions had caused substantial problems or had required guessing on their part. Because this may have been perceived as a difficult test, overall ratings of confidence may have been suppressed. Future research investigating the relationship between levels of confidence and the use of analogies should consider comparisons of confidence levels before and after posttest completion. Furthermore, if enjoyment ratings were collected prior to the posttest it might be expected that higher perceptions of enjoyment would also be reported.

General Discussion

In conclusion, several lines of reasoning converge to suggest that analogies are potentially powerful instructional tools: (a) their persuasiveness in both everyday and instructional communication (Curtis & Reigeluth, 1984; Duit, 1991), (b) anecdotal evidence of their influence in scientific discoveries throughout history (Gentner & Jeziorski, 1990), and (c) empirical evidence of their effectiveness in a variety of learning tasks (e.g., Andrews, 1987; Anderson & Thompson, 1989; Halpern, 1987). However, what has been written about analogies is mostly descriptive in nature. Duit (1991) notes that even in textbooks that make excellent use of analogies, no guidance is given as to how to effectively use those analogies in instruction. Thus he concludes that analogies are not as effective in the classroom as they could be. There is little prescriptive information available for teachers, and as a result, few guidelines for using analogies in instructional practice. Glynn (1991), Newby and Stepich (1987), and Zeitoun (1984) have taken steps toward filling this gap by suggesting similar sets of procedural guidelines for both creating and utilizing analogies within instruction. The present investigation was undertaken as an empirical test of one of their prescriptions: that analogies can increase immediate, as well as delayed, recall and application of concepts. The primary finding confirmed this assumption.

Conclusions about the influence of analogies on the comprehension of concepts in the present study are strengthened by the fact that students in the analogy condition were not trained in the use of analogies. Moreover, the use of prompts or cues to remind participants to use the analogies did not significantly impact the performance of learners compared to those who did not receive prompts. Contrary to this finding, previous research (Gick & Holyoak, 1980, 1983; Reed, Dempster, & Ettinger, 1985; Schustack & Anderson, 1979) has indicated that training and cues are essential aspects of using analogies effectively in instruction. Clement (1993, p. 1259) has insisted that for instructional analogies to be effective, ". . . more effort than is usually allocated must be devoted to making analogies plausible to students". Additionally, Duit (1991, p. 656) concludes, ". . . it appears legitimate to conclude that spontaneous use of analogy is quite common in everyday life as well as in problem solving, but that the use of fruitful analogies provided by teaching and learning media requires considerable guidance." However, the students in the present investigation did not receive explicit training in using analogies prior to completing the posttests yet, those in the analogy condition significantly outperformed students in the no-analogy condition across both studies. This indicates that explicit training and prompting are not always necessary and that analogies may facilitate concept learning without these additional features. Still, it should be pointed out that these participants were college students, and thus advanced learners, who may have had years of experience with the use and interpretation of analogies. Less experienced learners may require additional training and prompting to achieve similar results. Additionally, the fact that the instructional materials were pilot tested before actual use could also have facilitated learners' use of the analogies; those analogies that may have caused problems for this audience were either modified or removed from the materials before final implementation. Further research is needed to explore the potential contribution training and prompting could make to the effectiveness of analogical

instruction as well as to determine optimal methods and timing for the delivery of such training and prompts.

Another area for future research is the type of prompts and cues which might prove most needed and beneficial. One alternative is to vary the amount of information contained within the prompts and then measure the degree of analogy recall and application attained by the learner. Additional supplied information within the prompt may allow for easier recall of the analogy but may also impact the level of processing required by the learner. In a related issue, Clement (1993) suggests the need for intermediate bridging examples as a means to ensure that the learners actually understand and comprehend the analogy. Research on prompts that include such bridging examples instead of just simple reminders for analogy use could provide valuable information for the improvement of overall analogy instruction.

Finally, questions about the benefits of self-generated versus supplanted analogies can be asked. Previous research has indicated some success with having students generate their own analogies based on their own experience and knowledge bases (Cosgrove, 1991; Wong 1993). However, can learners economically and repeatedly generate and employ analogies in an effective manner? Harrison and Treagust (1993) suggest that training can help learners accomplish this; while Thagard (1992) suggests a sort of "analogy therapy" as a way to point out misunderstandings and generate more illuminating analogies.

Although research has indicated the value of self-generated analogies due to the relevance and the deep level of processing required to generate an analogy (Smith & Ragan, 1993), it may also be valuable to further examine how supplanted analogies are used by learners. In some cases it may be that the presented analogies are accepted and used without question; other times, the presented analogy may be adapted, altered or replaced by the learner. The presented analogy may serve as a prompt, cue, or an example on which the learner can build. Qualitative studies examining how presented analogies are used by both successful and not-so-successful learners could reveal important information in this regard. Although analogies have been generally shown to be effective, further research is needed to explore why and how those benefits can be maximized for all learners.

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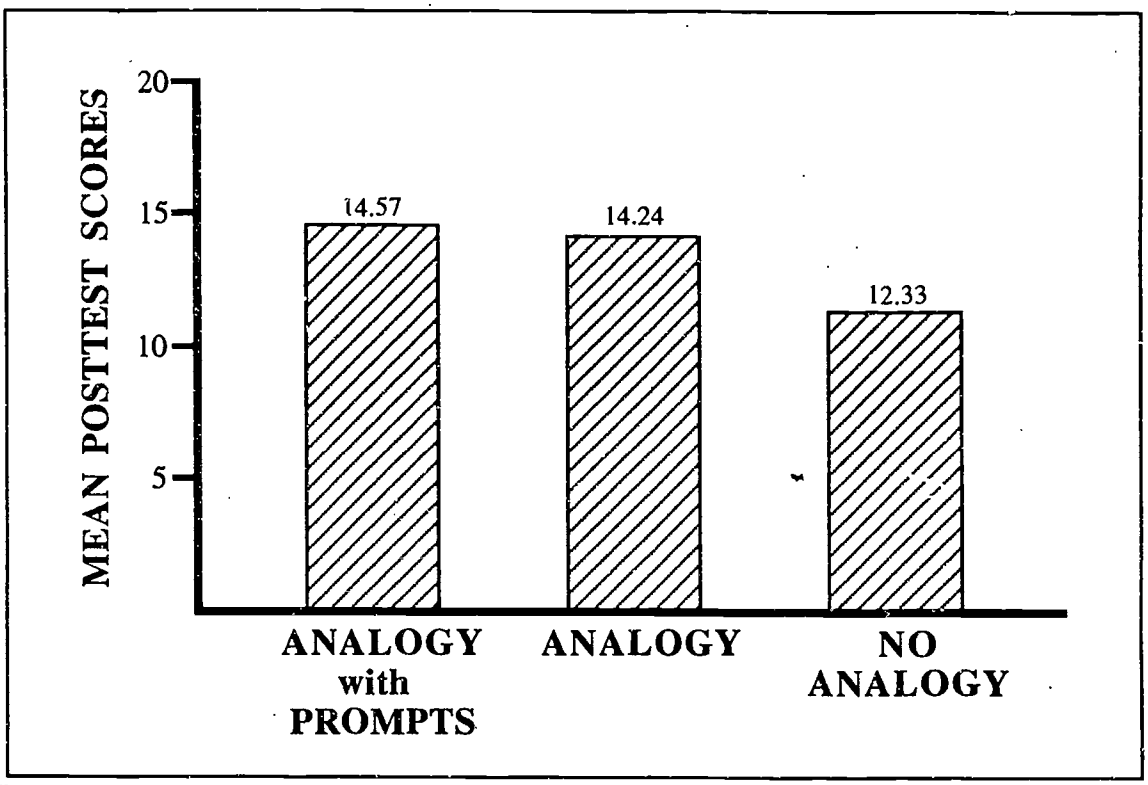

Figure 1. Immediate posttest mean scores comparing analogy with prompts, analogy without prompts, and no-analogy trained subjects.

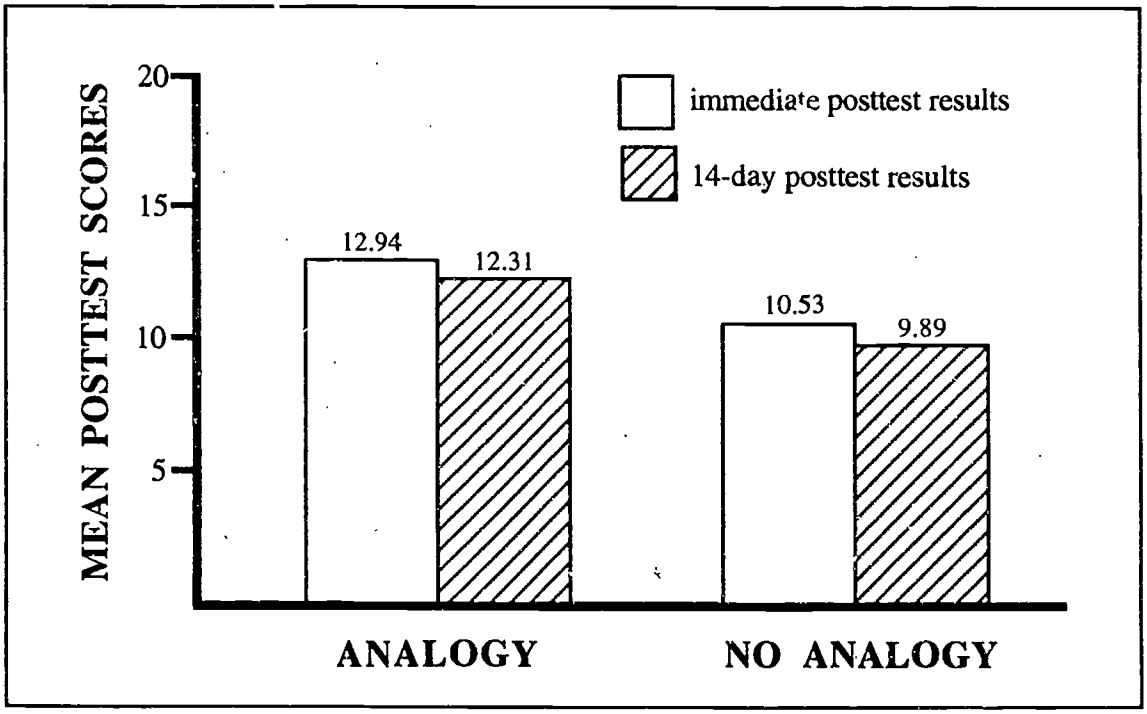

Figure 2. Immediate and 14-day posttest mean scores comparing analogy and no-analogy trained subjects.