# THE USE OF ANALOGIES IN LEARNING SCIENTIFIC CONCEPTS IN PSYCHOLOGY

Allan B.I. Bernardo
*University of the Philippines*

*One experiment was conducted to determine the effects of using analogies in learning concepts in psychology. Subjects were presented information about various concepts in study texts written either in literal form or by way of analogy to a more familiar concept. All subjects were then given two types of test questions that refered to the concepts: basic-level questions that tested for memory for information given in the study text, and inference-level questions that test for reasoning beyond the information given in the study text. Results show that subjects who studied the concepts using analogies performed better on the inference-level questions but worse on the basic-level questions. It was concluded that using analogies enhances learning by facilitating inferential thinking, but that it may also hinder learning of and memory for unique elements of the concept. The implications of and the mechanisms for these effects are discussed.*

People often come to understand a new concept by way of comparing it to a familiar concept. In grade school we were taught about the earth's rotation by comparison to a spinning toy top or ball and about fractions by comparing 3/4 to three slices of a quartered pie. This manner of understanding a concept is called understanding by analogy. Elaborating on concepts by way of analogies (and metaphors and similes) has also been used extensively in teaching psychological concepts. Most psychology students develop an appreciation of the significance of the Freud's unconscious by refering to that which is beneath the "tip of the iceberg". Students come to understand the dynamic relationship between the id, ego, and super ego by seeing its similarities to hydraulic pressure. This experiment is an investigation into the specific effects of using analogies in learning psychological concepts.

The benefit of using analogy to elaborate on concepts has been long debated in the psychological literature. For example, there are alternative views regarding why the use of analogies should benefit learning. One view states that analogies enhance learning by promoting more elaborative memory encoding processes (Mayer & Bromage, 1980; Schustack & Anderson, 1979). What analogies do is to provide a framework for organizing the knowledge to be acquired so that it will be remembered more completely. The assumption is that more enhanced learning is based on more complete memory of the target information. An alternative view states that analogies enhance learning by making the target information more concrete (Mayer & Gallini, 1990, Paivio, 1986). The assumption of this view is that information that is more concrete can be manipulated more easily, thereby facilitating the process of thinking about the new information. However, the predominant view is that analogies help because the processes of analogical mapping results to the construction of more sophisticated mental representations of knowledge (see e.g., Anderson & Thompson,

1989; Bernardo, 1994; Catambrone & Holyoak, 1989; Cummins, 1992; Gick & Holyoak, 1983; Novick & Holyoak, 1991; Ross & Kennedy, 1990). These advanced mental representations describe the abstract elements of the relevant problem domains, and therefore, allow for more elaborate and systematic thinking within the new domains to be learned.

A more basic debate about the role of analogies in learning concerns whether analogies actually enhance learning and thinking skills. Spiro, Feltovich, Coulson, & Anderson (1989), for example, asserted that using analogies might lead the student to make incorrect inferences by applying and extending inappropriate information from one domain to another. For example, describing the accomodative function of the crystalline lens in the eye as being similar to the focussing function of the lens in the camera could mislead students about the mechanism of accomodation. For one, students often incorrectly infer that, similar to the lens of the camera, light is refracted in the eye primarily through the crystalline lens (light is actually refracted primarily in the front part of the cornea). Students also incorrectly infer that, similar to the camera's lens, the crystalline lens achieves in accomodative function by changing its position (accomodation is achieved by changing the shape of the crystalline lens). It is possible, therefore, that analogies may misdirect the student.

However, other psychologists like Holland, Holyoak, Nisbett, and Thagard (1986; see also Holyoak and Koh, 1987) have argued that using analogies allows students to generate more inferences about the material to be learned. If this assertion were true, it would provide strong arguments for more extensive use of analogies in enhancing learning and thinking skills. Unfortunately, evidence for this position is sparse and inconclusive. Halpern (1987), for example, found no difference in performance on inference-level questions between subjects who studied concepts in analogical or literal presentations. Vosniadou and Schommer (1988) found that using analogies, compared to literal presentations, did not necessarily lead to generating more inferences, but it did not induce more erroneous inferences either. Most recently, in a series of experiments, Donnelly and McDaniel (1993) found that students answered inference-level questions about a topic better when the concepts are presented through analogy compared to when the concepts were presented literally. Their evidence is the best evidence so far about the enhancing effect of using analogies on inference-level thinking. This judgment is based on the fact that they consistently replicated the enhancement effect in four separate experiments. There is still a strong need, however, to further study the effect of using analogies on inference-level thinking in order to better understand the function of analogies in learning and to better motivate the application of using analogies in instruction.

This study a replication of the basic Donnelly and McDaniel experiment. However, the current study investigates the effect of using analogies in learning psychological concepts. The pragmatic importance of this replication should be obvious. Psychologists have the vested interest of determining whether certain strategies would facilitate students learning of concepts, principles, models, and theories in the discipline of psychology. However, there is a more theoretical motivation for replicating the study using psychological concepts. Donnelly and McDaniel studied concepts in the domain of the physical and natural sciences (i.e., physics — astrophysics and optics, biology, and physiology). Concepts in these domains were elaborated using analogies with familiar, concrete objects and events. On the other hand, psychological concepts and processes are more abstract in character. Most psychological concepts relate to entities and operations that are not readily accessible to the senses. Therefore, elaborating on these concepts using analogies would necessarily refer to less concrete and more complex objects and events. Considering this non-trivial difference in

the nature of the concepts, it is conceivable that the effects of analogies on learning psychological concepts might be very different from the effects of analogies on learning concepts in the physical and natural sciences.

Out of the several independent variables studied by Donnelly and McDaniel, only two variables were studied in this replication: mode of presentation and type of test question. Mode of presentation refers to the manner in which a concept or a theory is rendered. One way of presenting information is by a straightforward, literal exposition on the pertinent pieces of information. The following paragraph is an example of a literal rendering of the mental resource model of Kahneman (1973):

> According to Daniel Kahneman, any mental activity that a person executes is effortful. The person has to use some amount of mental resources in order to execute the activity. Various activities differ in terms of their complexity and therefore in the amount of mental resources required to execute them. The brain uses a resource allocation policy to determine which activities will receive specific amounts of resources from the fixed amount that is available.

In the preceding paragraph, the student can come to learn about a psychological proposition by constructing and developing her knowledge about that single, specific domain. However, the same material can be rendered in analogical form. The various concepts can be elaborated on by reference to a more familiar set of concepts, as described in the paragraph below:

> According to Daniel Kahneman, any mental activity that a person executes is effortful. The person has to use some amount of mental resources in order to execute the activity (in the same way that a city needs electricity for its different areas). Various activities (or areas of the city) differ in terms of their complexity (or energy requirements) and therefore in the amount of mental resources (or electricity) required to execute them. The brain (like NAPOCOR) uses a resource allocation policy to determine which activities (or areas) will receive specific amounts of resources (or electricity) from the fixed amount that is available.

In the preceding paragraph, the mental resource model is described in terms of a familiar set of concepts that relate to electricity, varying electrical demands, and rationing of electricity. The student can learn about a new psychological proposition through her knowledge about another, more familiar domain of knowledge.

The other variable studied in this experiment was the type of question. Two types of questions were studied: basic-level and inference-level questions. Basic-level questions refer to pieces of information that are explicitly stated in the studied material. For example, a basic-level question about mental resource models could be: "The brain uses a _____ to determine which tasks will receive specific amounts of energy". Inference-level questions require that the student go beyond the information stated. The student is required to derive the answer by reasoning from the given pieces of information. The following is an example of an inference-level question: "What would likely happen if there are several tasks and there are not enough resources for all of them?"

How would performance in these two types of questions be affected by the mode of presentation? Consistent with the findings of Donnelly and McDaniel, it was predicted that for the inference-level questions, subjects who studied the concepts in analogical form would perform better than those who studied the concepts in literal form. On the other hand, for the basic-level questions, the reverse would be true. Processing an analogy requires that the

individual establish mappings between the various elements of the two conceptual domains — the source domain or the familiar concept and the target domain or the new concept (Gentner, 1983; Holyoak, 1985; Reed, 1987). If the individual understands the various elements of the source domain, the mapping of elements allow the individual to develop some understanding of the various elements of the target domain. More importantly, the individual can speculate about the target domain based on her knowledge about the source domain. Therefore, it was predicted that analogical learners would be better able to cope with the reasoning requirements of the inference-level questions. On the other hand, the act of focusing on similarities between the source and target domain might draw away attention from the specific details of the target domain. Thus, it was predicted that for basic-level questions, analogical learners might be at a disadvantage.

To summarize, one experiment was conducted to study the specific effects of using analogies in learning concepts in psychology. It was predicted that analogical learners will perform better than literal learners on the inference-level questions, but analogical learners will perform worse than literal learners on the basic level questions.

## METHOD

### Subjects

The subjects of the experiment were 94 Introductory Psychology students at the University of the Philippines, Diliman who participated as part of a class requirement. The students participated during the middle part of the semester when most of the concepts have not yet been studied. Half of the subjects were randomly assigned to the analogy condition, and half to the literal condition.

### Materials

Ten psychological concepts were chosen from Introductory Psychology textbooks. The concepts were labelled: *the modern brain, the retina, speech production, mental resources, automatized tasks, focal attention, memory organization, retrograde amnesia, conceptual categories, and problem solving.*

For each concept, a short paragraph discussing specific elements of the concept was written. These paragraphs were used as the study texts in the literal condition. The same paragraphs were modified to include references to a familiar topic. These modified paragraphs were used as the study texts in the analogy condition. To test learning of the various concepts, four questions were created for each concept: two basic-level questions and two inference level questions. All the questions were multiple-choice type questions with four choices. (The study texts and question for *the modern brain* and *the retina* were adapted from Donnelly and McDaniel 1993.) The Appendix describes examples of study texts in literal and analogy form and the corresponding basic-level and inference level questions.

The concepts were divided into two clusters. The first cluster consisted of *the modern brain, the retina, speech production, mental resources,* and *automatized tasks;* the second cluster consisted of *focal attention, memory organization, retrograde amnesia, conceptual categories,* and *problem solving.* For both clusters, the five study texts were printed on one page. The four questions for each of the five concepts in a cluster were printed in the same sequence as the study texts. For all the concepts, the two basic-level questions always preceded the two inference-level questions. For both cluster, the questions were printed in four pages. The different materials were combined to form test booklets. Each test booklet contained (a) one page of instructions, (b) one page of study texts, (c) four pages of the corresponding test

questions, (d) one page of the remaining study texts, and (e) four pages of the corresponding test questions. The materials for (a), (b), and (d) were varied depending on the mode of presentation; the materials for (c) and (e) were the same for all subjects. The sequence of the two clusters was counterbalanced across subjects.

### Procedures

Subjects participated in groups not larger than twelve. Each subject was randomly assigned to a mode of presentation condition by the random distribution of test booklets. Each subject began by reading the instructions. The subjects in the literal condition were told that they will be asked to study paragraphs discussing different concepts in psychology. The subjects were given an example of a study text. The subjects were then told that they would be required to answer questions that refered to the concepts they studied. They were also given an example of a question.

After reading the instructions, the subjects were given 10 minutes to study the first five concepts. The subjects were then given another 10 minutes to answer 20 multiple choice questions. They were not allowed to refer directly to the study texts in answering the questions. They were then given another 10 minutes to study the remaining five concepts, and another 10 minutes to answer the last 20 questions. Subjects progressed from one part of the experiment to another all at the same time. Subjects who finished before the given time was over were not allowed to proceed to the next part until the proper time.

## RESULTS

The experiment was conducted to test the hypothesis that subjects in the analogy condition would perform better than those in the literal condition in the inference-level questions but worse in the basic-level questions. To verify this hypothesis, the proportion of correct responses for the 20 basic-level and the 20 inference-level questions were computed for each subject. The proportions of correct responses were analyzed using an Analysis of Variance for 2 x 2 mixed factorial design, with mode of presentation as between-subject variable and type of question as within-subject variable. The ANOVA showed no main effect of mode of presentation, $F(1, 92) < 1$. Across type of questions, subjects in the analogy condition (x = 64.26%). The ANOVA also revealed a main effect of type of item, $F(1, 92) = 345.55$, $MSe = 0.007$, $p<.0001$. Across modes of presentation, subjects performed better on the basic-level questions (x = 75.72%) compared to the inference-level questions (x = 52.61%). This main effect can be attributed to the overall difficulty of the inference-level questions compared to the basic-level questions. The latter simply requires that the subject recall the information given in the study text while former requires that the subject derive the answer by reasoning from the given information.

The true test of the experimental hypothesis is the interaction effect. Consistent with the hypothesis, there was an interaction effect between mode of presentation and type of question, $F(1, 92) = 16.48$, $MSe = 0.007$, $p<.0001$. To test the hypothesis in greater detail, the pertinent means were compared using a t-test for pairwise comparisons. For the inference-level questions, subjects in the analogy condition performed better than subjects in the literal condition (55.21% vs 50.00%), $t(92) = 2.11$, S.D. $= 0.014$, $p<.04$. On the other hand, for the basic level question, the effect was the exact opposite. Subjects in the analogy condition performed worse than subjects in the literal condition (73.30% vs 78.19%), $t(92) = 1.97$, S.D. $= 0.015$, $(p = .05)$.

## DISCUSSION

One experiment was conducted to determine the specific effects of using analogies in learning concepts in psychology. The results show that the use of analogies facilitates inferential

thinking about the newly acquired concepts, but hinders learning of and memory for the unique elements of the new concept. The results replicate the basic finding of Donnelly and McDaniel and provide further evidence for the view that analogies enhance learning of concepts, in particular, by facilitating inferential thinking about the concept. This type of data is important in resolving the debate about whether or not analogies help the learning process at all. More significantly, the data demonstrate the benefit of using analogies in learning concepts in psychology. It was noted earlier, that concepts in psychology are different from the physical and natural science concepts studied in earlier reasearches on the effects of analogies on learning. The data suggest that these differences in the character of concepts do not substantially affect the nature of the specific effect analogies have on the process of learning.

This specific effect seems to be consonant with the models that describe the processing of analysis as involving a mapping of elements between the source and target domains (Gentner, 1983; Holyoak 1985; Reed, 1987). These models propose that a learner comes to understand a new concept by way of using what she knows about a more familiar concept. The learner makes sense of the different specific elements of the new concept by relating it to specific elements of a concept that she already understands. Using what the learner knows about other elements of familiar domain, she can then speculate about related elements about the new domain — elements that have not been explicitly described in the given information. Hence, we observe that using analogies facilitates inferential thinking about the target domains.

Inferential thinking is an important skill that needs to be developed among students of any discipline. It is only by inferential thinking that knowledge in a domain can be expanded and extended. It is by inferential thinking that we expand our theoretical understanding of various phenomena. By reasoning from our current empirical and theoretical knowledge, we can develop an understanding of more specific elements of the domain of knowledge. An end good of this inferential process is a complete theoretical account of the target phenomena. Therefore, it would be difficult to overestimate the importance of developing inferential thinking in a developing discipline like psychology. It is also by inferential thinking that we can extend our knowledge about a domain to apply to different problems that beset our society. Most basic psychological theories in psychology have significant implications and applications for a wide range of concerns. However, these implications and applications are not always directly accessible. Psychologists and students of psychology need to engage in inferential thinking and go beyond the specific assumptions of theories in order to see how knowledge can be put to use.

While it is now evident that using analogies would lead to inferential thinking, we should note that research has shown that people do not spontaneously engage in analogical processing unless there is high degree of similarity between the source and target domains (Gick & Holyoak, 1980; Novick, 1988; Reed, Dempster, & Ettinger, 1985; Ross, 1984, 1987, 1989) or unless people are explicitly prompted to engage in analogical processing (Cummins, 1992; Gick & Holyoak, 1983, Novick & Holyoak, 1991; Ross & Kennedy, 1990). An implication of these earlier research findings is that if we wish to develop inferential thinking by using analogies, teachers should structure the analogies for the learner. Leaving the student to discover the analogical relations by herself will not work. Instead, the analogical similarities should be explicitly pointed to the students in order to prompt the analogical process.

Lest we forget, the experimental data also showed that using analogies hinders learning of and memory for the specific unique elements of the novel domain. This effect could be explained by the view that analogical processing focusses on the abstract, relational similarities between the elements of the target domain and the source

domain. Therefore, this focus draws attention away from the unique elements of the target domain that are not related to the known elements of the source domain. As Donnelly and McDaniel noted, however, it is yet unclear whether this attenuating effect on memory is a necessary side effect of the process that facilitates inferential thinking. It is conceivable that the presentation of information could be structured such that elaborating by analogy does not draw attention away from the other elements of the concepts to be learned and remembered. For example, the literal information could be presented first. The information could then be restated in analogical form. This type of presentation of information could be studied in future experiments. Such efforts are clearly necessary so that someday it may be possible to develop the optimal learning and instructional strategies that will lead to both basic learning and memory and inferential thinking about concepts.

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## AUTHOR NOTES

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Correspondence concerning this article should be addressed to Allan B. I. Bernardo, Department of Psychology, Palma Hall Annex, University of the Philippines, Diliman, Quezon City 1101.

## APPENDIX

## EXAMPLES OF STUDY TEXTS AND TEST QUESTIONS

### *Literary study texts*

*Focal Attention.* The human perceptual system is constantly bombarded with a wide range of stimuli from the environment. However, the perceptual system does not process all of these stimuli all at once because not all these are useful or are of interest. According to Michael Posner, the perceptual system uses *focal attention* to limit the range of stimuli to be processed. By limiting the processing to the stimuli in the focal region, processing of the information is enhanced.

*Retrograde Amnesia.* People who suffer from *retrograde amnesia* forget events that happened before the cause of the amnesia. It has been suggested that this phenomenon is due to failure in *trace consolidation.* Newly acquired memories or *memory traces* need to undergo a gradual change in order to become resistant to any disturbance. The memory traces about events before the amnesia have not yet, hence, these were lost.

### *Analogy study texts*

*Focal Attention.* The human perceptual system is like a director of a play with many actors: both are constantly bombarded with a wide range of stimuli from the environment (like the many actors performing on a stage). However, the perceptual system (or director) does not process all of these stimuli (actors) all at once because not all these are useful or are of interest. According to Michael Posner, the perceptual system uses *focal attention* (like a director uses a spotlight) to limit the range of stimuli to be processed. By limitting the processing to the stimuli in the focal region (or the actor covered by the spotlight), processing of the information is enhanced (or the actor's performance can be highlighted).

*Retrograde Amnesia.* People who suffer from *retrograde amnesia* forget events that happened before the cause of the amnesia. It has been suggested that this phenomenon is due to failure in *trace consolidation.* Newly acquired memories or *memory traces* need to undergo a gradual change (like cement needs to harden) in order to become resistant to any disturbance. The memory traces about events before the amnesia (like fresh cement) have not yet (or is still wet and soft), hence, these were lost.

### *Basic-Level (Numbers 1 and 2) and Inference-Level (Numbers 3 and 4) Test Questions*

*Focal Attention*

1. According to Posner, focal attention refers to _____.

   a. filtering perceptual information for processing.
   b. limiting the range of perpetual input to be processed
   c. the act of making perceptual processing faster
   d. setting expectations for specific perceptual information

2. Using focal attention guarantees _____.

   a. faster processing of perceptual information.
   b. enhanced processing of perceptual information

c. enough perceptual resources for the entire visual field
d. that the perceptual system will not be overextended

3. Based on your knowledge about focal attention, you could predict that perceptual processing when attention focusses on a smaller region should be _____ when attention focusses on a bigger region.

a. more efficient than
b. less efficient than
c. as equally efficient as
d. faster than

4. What would most likely happen if the perceiver wishes to look at a perceptual object that is currently not the focus of focal attention?

a. This not possible because the perceiver would not be able to know about the new object in the first place.
b. The use of focal attention would be stopped and the entire visual field will be processed.
c. The use of focal attention would be stopped and then reactivated on the new object.
d. Focal attention would sweep towards the new object.

***Retrograde Amnesia***

1. People with retrograde amnesia have no memories for _____.

a. any type of event
b. events that occured after the onset of amnesia
c. events that occured before the onset of amnesia
d. events related to the cause of the amnesia

2. Retrograde amnesia is said to be due to failure in _____.

a. rehearsal in memory
b. facilitation in retrieval
c. trace consolidation
d. information integration

3. People who suffer from retrograde amnesia should be more likely to have memories for events _____ the onset of amnesia, compared to events _____ the onset of amnesia.

a. immediately before; much earlier than
b. much earlier than; much later before
c. immediately after; much later than
d. much later than; immediately after

4. People can recover from retrograde amnesia, but not completely. Based on what you know about retrograde amnesia, these patients would most likely never recover their memories for _____.

a. events immediately before the onset of amnesia.
b. events immediately after the onset of amnesia.
c. their earliest experiences from childhood.
d. the event that caused the amnesia.