Educational Technology International
2008, Vol. 9, No. 1, 79-96

Analogical Transfer: Sequence and Connection

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The issue of connection between entities has a lengthy history in educational research, especially since it provides the necessary bridge between base and target in analogical transfer. Recently, the connection has been viewed through the application of technology to bridge between sequences in order to be cognitively useful. This study reports the effect of sequence type (AT vs. TA) and connection type (fading vs. popping) on the achievement and analogical transfer in a multimedia application. In the current research, 10th –grade and 11th –grade biology students in Korea were randomly assigned to five groups to test the effects of presentation sequence and entity connection type on analogical transfer. Consistent with previous studies, sequence type has a significant effect: analogical transfer performance was better when base representations were presented first followed by target representations rather than the reverse order. This is probably because presenting a familiar base first helps in understanding a less familiar target. However, no fully significant differences were found with the entity connection types (fading vs. popping) in analogical transfer. According to the Markman and Gentner's (2005) spatial model, analogy in a space is influenced only by the differences between concepts, not by distance in space. Thus connection types fail on the basis of this spatial model in analogical transfer test. The findings and their implications for sequence and connection research and practice are discussed. Leveraging on the analogical learning process, specific implications for scaffolding learning processes and the development of adaptive expertise are drawn.

Keywords : analogical transfer, sequence and connection, scaffolding learning process, adaptive expertise

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Introduction

Background to the Research

The use of analogy is an important mechanism for conceptual growth. The core benefit of using analogy is that the learner can apply a familiar structure or mental model to ascertain fundamental and relevant relations in the target domain (Gentner, 1983; Shustack & Anderson, 1979). For example, Figure 1 and Figure 2 illustrate how a learner could apply prior knowledge about a factory system to conceptualize an animal cell in biology class.

In this case, the familiar domain called the *base* provides a way to assimilate and structure an unfamiliar domain called the *target*, and serves as a base of hypotheses about the new domain (Clement, 2002). " Familiar domains (e.g., factory) often serve as early mental models that students use to form limited meaningful understandings of more complex concepts (e.g., animal cell)" (Paris & Glynn, 2004, p. 232). For example in Figures 1 and 2, the familiar base is a factory (Figure 1) and the target concept is an animal cell (Figure 2). By aligning features of the familiar factory with those of the animal cell, the analogy presumably can act as a mediator and make the corresponding features of the animal cell more meaningful and memorable. As the learners develop cognitively and learn more science, they adopt more sophisticated and powerful models.

With some important exceptions, the cognition of analogical processing has mostly been ignored by instructional designers. This is a serious oversight because analogical processing lies at the heart of all original thought (Petrie, 1979, cited by Winn, 1982). Analogical processing relies upon a schema that is sufficiently abstract to accommodate the association of an unfamiliar domain which is related, albeit distantly, to a familiar domain (Winn, 1982). A variety of factors can influence the use of this analogical processing, and the research reported here will examine two: namely sequence (whether the base comes first or the target does) and connection type (how the entities are connected across domains). The factors affecting transfer are still poorly understood and the task used in this and in previous work may not lend itself to the study of real-world transfer.

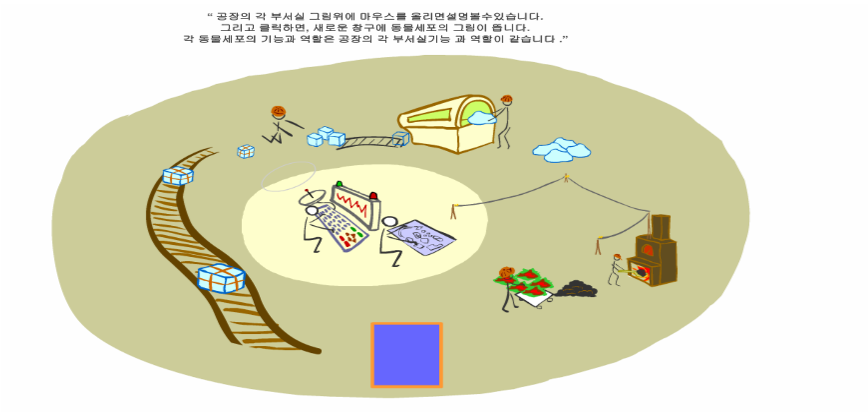

Figure 1. Example of Analogy Base (Factory)

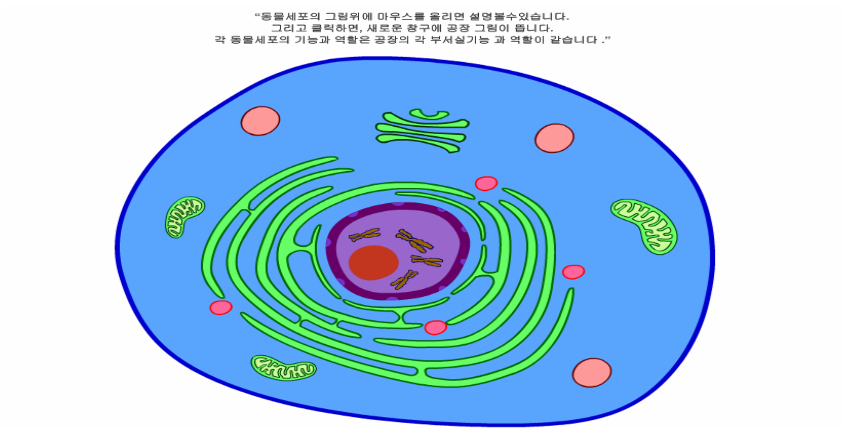

Figure 2. Example of Analogy Target (Animal Cell)

Definition of Analogy

The definition of analogy that has been used to span these alternate forms derives from Gentner’s (1983) formalization. Her definition is:

> "Analogy is a comparison in which relational predicates, but few or no object attributes, can be mapped from base to target"(p. 159).

Analogy is a process mapping a relational structure between a familiar domain, termed the "*base*" or "*source*" of the analogy, and a relatively unfamiliar domain, termed the "*target*" of the analogy. In structure-mapping, analogy is defined as mapping of knowledge of a familiar domain (the base) into another, usually less familiar domain (the target) (Gentner, 1983).

Analogical Transfer

Analogy has led to delineation of the processes comprising the steps in human analogical reasoning. Relevant components of analogy are argued to be: selection of a base, selection of a target, alignment between these analogs, making system mappings, drawing inferences from the base about the target, evaluating and adapting these inferences to the target domain, and promoting new learning (Holyoak, Novick, & Melz, 1994). A distinction is drawn here between components of analogical reasoning and analogical transfer. Holyoak and Thagard (1989) argue that an analogy is established by the mapping stage. An analogy is defined as aligning two objects systematically according to relevant relations. Analogical transfer is defined, by contrast, as the process of bringing a relevant set of relations from one object to bear on another object. Inferences about the latter object are drawn on the basis of the base relations, and these are adapted to the particular target object.

The Sequence and Connection Application

In this study, a computer software application called *Sequence and Connection* (SC) was created to study the effects of sequence and connection on analogical learning. SC and the study two methods for sequence and two for connection: the sequence is either base first (and target second) or target first (and base second); while the entity connections are made using either fading (one entity fades out and the other fades in) or popping (a new window pops up with the corresponding entity show in the context of the analogous domain). The SC program is based on structure mapping theory, and serves to test our hypotheses in the experiment but also as a learning tool. Combining these sequence and connection possibilities yields five groups: AT-F (base analogy then target using fading), AT-P (base analogy then target using pop-up), TA-F (target then base analogy using fading), TA-P (target then base analogy using fading), and Control (no analogy). Figure 3 and Figure 4 show *connection* examples of popping and fading. The analogy used in this study was created and developed using multimedia. Objects in the base are mapped in one-to-one correspondence with objects in the target. For example, in Figures 3 and 4, security work is used in the factory to check up on raw materials and production. In the case of the animal cell, the membrane illustrations and annotation is used to show how the animal cell works. The sequence consists of AT and TA that is the order of the factory (base) vs. animal cell (target) and vice versa. Connection consists of the fading and popping. In the sequence and connection three steps are involved to activate the learning phase for each group: (1) read and listen to instruction, (2) mouse over, and (3) click the picture to get pop-up or dissolve.

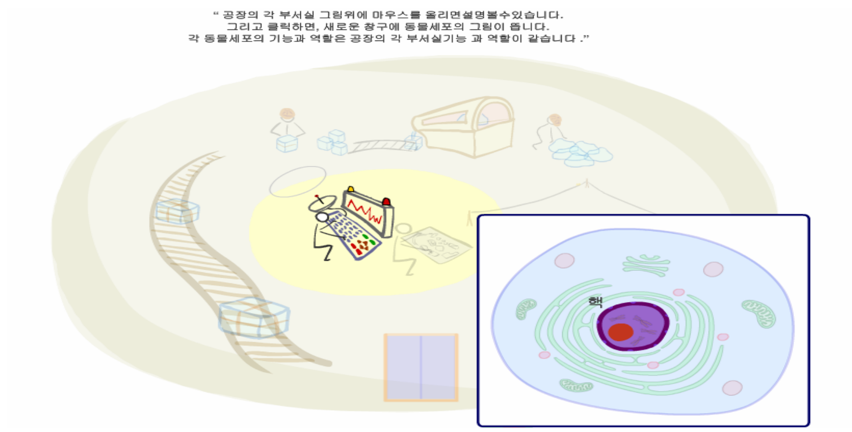

Figure 3. Popping (Connection Type).

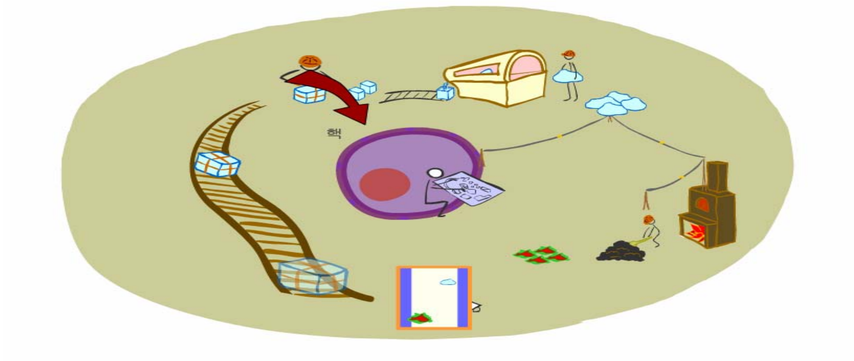

Figure 4. Fading (Connection Type).

This study investigates the use of the sequence and connection and uses a multimedia platform to study the interplay of sequence and connection. These are necessary elements of analogical comparison. Sequence is realized by the presentation order of base and target images. Connections between images are realized through a fading (fading images) or a popping (pop-up images).

Research Objective

Despite extensive work on mechanisms of analogy, there has been very little discussion of why and how components of sequence and connection are important in cognitive processing. To investigate this, we first outline three different approaches to analogical learning: i) the effect of two connections (fading vs. popping); ii) the effect of two sequences (base to target vs. target to base); iii) the interaction of sequence and connection. This study employed data from middle school-aged participants over three instruments. The participants had to complete two tasks to measure knowledge: a drawing and a writing task: *the analogical transfer test used open-ended questions* to examine the "between sequence" and "between connection" conditions. The second instrument was a questionnaire in which participants indicated their prior knowledge of the domain content, their degree of interest in the domain content, and their degree of motivation to complete the tasks.

This study will implement notions of sequence and connection in an effort to enhance our understanding of the role of analogy in the learning process.

The Sequence & Connection Research Question

Q1: Does the Analogy -Target (AT) group report better analogical transfer than the Target-Analogy (TA) group?

Q2: Does the fading group report better analogical transfer than popping group?

Method

Participants and Design

Participants

The participants were one hundred and twenty-eight 10th –grade and 11th –grade learners (N=128; 62 male, 66 female) in two period biology classes at their computer lab. All subjects were attending either a private or a public high school in Seoul, Korea. All were from Korea and Korean is their native language.

Participants were randomly assigned to 2x2, sequence (base-target vs. target-base) and connection (fading vs. popping) treatment and a control group. Because the number of participants and, thus, the number of groups varied across two schools, it was not possible to assign an equal number of participants to each group.

Study Design

The study involved a pre-test and post-test, four treatments, control-group design. The design for this study contained pre-test and post-test to see their learning development. The purpose of the pre-test was to see the learner's previous knowledge about base of analogy. The study was carried out in three phases as described below. The independent variable is an example representation format consisting of five levels.

Procedures

Settings

The experiment was conducted during the regularly scheduled Biology Lab course sessions, which have one-week duration, utilizing classroom PCs with 18" monitors at computer lab of the schools.

The following procedure steps were taken.

Phase 1: individual pre-test. Participants first responded to a web-based survey asking participants profile information. In the first phase (prior to learning), all participants individually took a pre-test on the target animal cell concepts and on the factory analogy test. Pre-test items on the achievement test were: for example, *please draw and label the parts of the animal cell you just studied* and p*lease write animal cell's name and their function.*

Phase 2: individual learning process. In the second phase, individual learning phase, all participants worked with their learning scenario. In this phase, participants were assigned to each learning scenario process based on the website. Participants could study their learning scenario as long as they wished.

Phase 3: individual pos-test process. In the third phase, all participants individually took two sections of the test. Post-test items were same as pre-test of achievement items. For example, p*lease draw and label the parts of the animal cell you just studied,* and p*lease write animal cell's name and their function.* But analogical transfer test items were 8 open-ended questions to connect base to target. For example, w*hat department or place does the nucleolus resemble in a factory? Why do you think so? The other one was what department or place does the cell membrane resemble in a factory? Why do you think so?* At the end of experiment, participants rated the usefulness and helpfulness of their learning scenarios on a 5-point likert-scale in response to the question: *Was annotation of animal cell helpful to understand animal cell, and was visualization of animal cell helpful to understand animal cell.*

Instrumentation

Materials

There were five web-based learning scenarios, AT-F, AT-P, TA-F, TA-P, and Control. These five learning illustration and annotation were developed from information in which Paris and Glynn (2004) used elaborate knowledge of a factory and an animal cell for base and target respectively in their research. As their study, the factory base (Paris & Glynn, 2004; Glynn, 1997), explains eight functions of a factory with illustrations and annotation-- for example, security work for checking raw materials and production with an illustration. However, as a target, animal cell uses illustration and annotation to explain how the animal cell works. Both scenarios were classified on the basis of their two hierarchical procedures; namely, sequence and connection as suggested by the literature. Sequence is the order of presentation of factory (base) vs. animal cell (target) and vice versa. Connection is fading vice versa composition as follows on the second page. Three steps were taken to activate the learning phase applicable to each group: read and listen to instruction, mouse over, and click picture, then pop-up or fade-in.

Measures

Background information

Participants first responded to a web-based survey asking participant profile information on the pre-test and post-test. Participants were required to provide background information in response to questions on gender, identity and group name. Participants were also asked to indicate their prior knowledge of the domain content, their degree of interest in the domain content, and their degree of motivation to complete the tasks. Upon studying with individual learning scenario, they were automatically directed to the entry page of the post-test. The post-test contained a measure: the *analogical transfer test* to evaluate analogical learning. These measure aimed to evaluate participants' understanding of target animal cells and connecting factory base to target animal cell.

Analogical transfer test

For each set of contents, participants' were given eight questions that were also divided into two parts: one part required a short answer and the other required writing the reason for the transfer. For each item, a score of 1 was given for a correct answer and 0 for a wrong answer.

Data Analysis Procedures and Methods

All of the data was recorded digitally and saved on the server in the Microsoft Access 2000 database program. The following data were collected and analyzed with Microsoft Excel and SPSS 14.

1. Preliminary Test. As a preliminary test, this study sought to investigate the level of prior knowledge of the animal cell. As additional preliminary test, the level of prior knowledge about factory base was determined using the pre-test. Low prior knowledge about the animal cell and high factory base knowledge was assumed. A descriptive table showing mean and standard deviation is used to support this investigation.

2. Effects of Sequence and Connection in Analogical Transfer Test. The possible range of analogical transfer is from 0 to 8. The first and second research questions examine the effects of sequence and connection in analogical transfer. To determine whether the groups differed from each other on the dependent variable, we used the one-way ANOVA, Dunnett t-test and univariate ANOVA to investigate mean differences between the two groups.

Results

Previous Knowledge Base and Target

This subsection reports the results which correspond to the first preliminary questions. Pre-test questions were analyzed to investigate if factory base was high and if animal cell knowledge was low. The study assumed that factory base was high but animal knowledge cell was low. As shown in Table 1 below, like factory base, prior knowledge was high and animal cell prior knowledge was low, which matched our assumptions.

Table 1. Means and Standard Deviations for Pre-Test (N=129)

	Pre-Test		
Group	*M*	*SD*	*N*
Factory Base Achievement	3.90	1.211	129
Animal Cell Achievement	.20	.523	128

The Sequence Type

This subsection reports results that correspond to the first and the second research questions. The range of possible scores analogical transfer were 8 on the sequence and connection. In addition, a 2 x2 univariate analysis of variance (ANOVA) was used with sequence analysis, averaged across the analogical transfer question, as the dependent variables. Qualitative analyses of the experience of content and interactional activity were used to further explain and support findings from the analysis of sequence and connection.

Q 1: The Analogy-Target group reports better analogical transfer than Target-Analogy group.

Table 2. Results in 2 x 2 Tables with Marginal Means in Addition to Condition Entries for Analogical Transfer.

		Connection		Total
		Fading	Popping	
Sequence	AT	5.46	5.26	5.36
	TA	5.04	3.97	4.50
Total		5.25	4.61	4.93

Table 3. Analysis of Variance Results for Sequence & Connection in Analogical Transfer

Source	SS	df	MS	*F*
Sequence	19.394	1	19.394	4.746*
Connection	10.607	1	10.607	2.598
Sequence x Connection	4.966	1	4.966	1.215
Error	416.826	102	4.087	
Total	454.642	105		

R^2 = .083 (Adjusted R^2 = .056)

*p < .05.

The results for the 2 x 2 ANOVA with the analogical transfer score as the dependent variable are presented in Table 3. They indicate a significant main effect for sequence (AT vs.TA) group, F (1,102) =4.746, p<.05, an insignificant main effect for connection (F vs.P) group, F (1,102) = 2.596, p > .05, and an insignificant interaction between sequence group and connection group, F (1,102) = 1.215, p > .05. The analogical transfer score mean for the AT group (5.36 out of 8 total possible, n=49, SD = .289) was significantly better than that for the TA group (4.50 out of 8 total possible, n=57, SD = .268). The findings support the Hypothesis 2 that the Analogy-Target group reports better analogical transfer than Target-Analogy group in sequence group.

In sum, as proposed in research question 1, it was found that there was a significant effect of sequence, i.e. analogy (base) before target and target before analogy (base), for analogical transfer task. Specifically, presenting an analogy before a target is better than presenting a target before an analogy as demonstrated from results of both a 2x2 ANOVA.

The Connection Type

This subsection reports the results corresponding to the second research questions by reporting 2 x2 univariate analysis of variance (ANOVA). According to the research question, 2 x 2 ANOVA conducted 2 factors with 2 levels: sequence (AT vs. TA) and connection (Fading vs. Popping) on the analogical transfer test. Table 2 report results in 2 x 2 table with marginal means in addition to condition entries for analogical transfer test. Table 3 reports the results of an univariate analysis of variance (ANOVA) for the effects of fading and popping groups on the analogical transfer. Again, the range of possible analogical transfer full score was 8 on the sequence and connection.

Q2: The fading group reports better <u>analogical transfer</u> than popping group.

The results for the 2 x 2 ANOVA with the analogical transfer score as the dependent variable are presented in Table 3. They indicate a significant main effect for sequence (AT vs.TA) groups, F (1,102) =4.746, p<.05, an insignificant main effect for connection (F vs. P) groups, F (1,102) = 2.596, p > .05, and an insignificant interaction between sequence group and connection group, F (1,102) = 1.215, p > .05. The analogical transfer score mean for the F (fading) group (5.25 out of 8 total possible, n=53, SD = 1.900) was significantly better than that for the P (popping) group (4.61 out of 8 total possible, n=53, SD = 2.207) in Table 2. But this finding did not support research question 2 that the Fading group reports better analogical transfer than Popping group in the connection condition.

In sum, the ANOVA revealed no significant difference between the connection groups, nor a significant interaction effect between sequence and connection.

However, an independent t-test showed a significant effect of connection for the TA group. In turn, analogical transfer was on fading case better than on the popping case.

Because the F test used in the ANOVA analyses represents values of squared components, a known drawback of the ANOVA test is its lack of specificity of directionality.

Discussion

The purpose of this study was to investigate the effects of sequence and connection, using either AT or TA, and the fading versus the popping in an analogical transfer task. The primary research question focused on analogical transfer tasks which required the participants to describe the eight-component by their connecting. Research question 1 and 2 investigated the effect of sequence type and connection type.

Effects of Sequence

Results were consistent with Paris and Glynn's (1997, 2004) previous research on the Sequence Type, which specified the order of base followed by target. The data provided strong evidence in support of this research question. There was a significant effect for sequence. Specifically, data supported presenting a base before a target over presenting a target before a base as demonstrated in Table 2 and 3.

The results described above are consistent with the findings of Glynn (1997) who also used a t-test in comparing elaborate analogy versus a control group. His hypothesis examined whether elaborate analogy can play a role when high school learners learn a concept from reading science text book. The present study's task content was similar to his base and target contents. The base was a factory and the target concept was an animal cell. The target features were eight parts of the animal cell and, by association, the functions of those parts. According to his assumption, by mapping the features of the familiar factory onto those of the animal cell, the analogy presumably acted as a mediator and made the corresponding features of the animal cell more meaningful and memorable.

Goldstone and Son (2005) performed a sequence-study. They found that both initial simulation and transfer performance was better when base representations were switched to more target representations halfway into a simulation. This means that familiar knowledge mode preceded by unfamiliar knowledge mode is more helpful for the learner. In this study's context, the sequence and connection demonstrated that it was best to show the security images and annotation before showing the cell membrane and other cell components.

Effect of Connection

Contrary to the Connection Type, the statistical analysis did not reveal a significant difference at the .05 level in the fading groups' performance over the popping group in the analogical transfer tasks.

Why were there no differences between fading and popping? According to Markman and Gentner (2000) the most important aspect of commonality and differences is that "structure mapping determines *which differences* in comparison are salient" (Markman & Gentner, 2000, p.514). This is one of reasons why there were no differences for the connection. Differences that are connected to the commonalities are more salient than differences not connected to matching structure (Markman & Gentner, 2000, p. 514). However, fading are not more salient than popping on connection of concept. Therefore, according to *salient differences*, there is no significant difference between fading and popping.

To better determine the reasons behind the insignificant results with regard to fading and popping, it is necessary to consult Markman and Gentner's (2005) recently study. They noted that spatial models have two major disadvantages as psychological models. "First, the comparison process gives rise only to a distance between concepts. The scalar value can be used to model similarity judgments, but there is no way to access the specific commonality and differences that form the basis of the similarity judgment. Second, similarity in a *space* is influenced *only by the differences* between concepts, not by their similarities" (Markman & Gentner, 2005, p.108). According to their statement, commonality and differences require the two aforementioned significant processing resources. How these two resources can support this argument is presented below.

Based on the spatial model, there is no distance between fading and popping. These differences that are connected to the commonalities of a pair are *not* rendered *more salient by comparison.* Commonality and differences are represented as fading and popping, but concepts are represented as analogical transfer of base and target. Therefore, *adding only distances* to the space along which two concepts which are the same will not increase similarity. However *adding distances* on which two concepts differ will decrease similarity (Markman & Gentner, 2000; Tversky, 1977). Because the spatial model does not capture commonality and differences for the above reasons, this connection type fails on the basis of the Markman and Gentner's (2005) spatial model and non-salient differences.

To conclude about theoretical implications, the results suggest that learning can be promoted by implementing sequence and connection. Inducing learners to evaluate analogical situation jointly can allow for the transfer of concepts and inference. According to Schwartz (1993), "by understanding the preconditions and catalysts of structure construction, it may be possible to design a sequence of instruction that capitalizes on learners' ability to build structure through visualizing" (Schwarz, 1993, p.1316). By encouraging learners to compare everyday situations and scientific situations, these implications may promote deeper understanding.

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