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The Effects of Problem Constraint Analysis on Analogical Transfer.

Ann Elizabeth Speed
Louisiana State University and Agricultural & Mechanical College

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THE EFFECTS OF PROBLEM CONSTRAINT ANALYSIS
ON ANALOGICAL TRANSFER

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in
The Department of Psychology

by
Ann Elizabeth Speed
B.A. University of New Mexico, 1993
M.A. Louisiana State University, 1996
August 1999
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Abstract

One primary goal of education, either in the schools or in a training situation, is for the students to use the information learned in the classroom in other relevant situations. This goal of transfer of training proves difficult to attain. Several manipulations used in the literature have increased transfer (Catrambone & Holyoak, 1989; Gick & Holyoak, 1980, 1983). However, all of these manipulations are not feasible for real-world use. The current experiments were designed to increase the ecological validity of manipulations and stimuli used previously by providing feedback to participants about their initial solution to a problem. Interestingly, the feedback manipulation had little impact on rates of transfer. Also, the current experiments did not replicate findings reported previously. It was concluded that the factors affecting transfer are still poorly understood, and that the task used in this and in previous work may not lend itself to the study of real-world transfer.
Introduction

Imagine that you are a subject in an experiment in which you are asked to read a story that goes something like the following:

A small country was ruled from a strong fortress by a dictator. The fortress was situated in the middle of the country, surrounded by farms and villages. Many roads led to the fortress through the countryside. A rebel general vowed to capture the fortress. The general knew that an attack by his entire army would capture the fortress. He gathered his army at the head of one of the roads, ready to launch a full-scale direct attack. However, the general then learned that the dictator had planted mines on each of the roads. The mines were set so that small bodies of men could pass over them safely, since the dictator needed to move his troops and workers to and from the fortress. However, any large force would detonate the mines. Not only would this blow up the road, but it would also destroy many neighboring villages. It therefore seemed impossible to capture the fortress.

However, the general devised a simple plan. He divided his army into small groups and dispatched each group to the head of a different road. When all was ready he gave the signal and each group marched down a different road. Each group continued down its road to the fortress so that the entire army arrived together at the fortress at the same time. In this way, the general captured the fortress and overthrew the dictator. (taken from Gick & Holyoak, 1983).

After reading this story, you are given a second story and are asked to offer a solution to it. That second story goes something like the following:

Suppose you are a doctor faced with a patient who has a malignant tumor in his stomach. It is impossible to operate on the patient, but unless the tumor is destroyed the patient will die. There is a kind of ray that can be used to destroy the tumor. If the rays reach the tumor all at once at a sufficiently high intensity, the tumor will be destroyed. Unfortunately, at this intensity the healthy tissue that the rays pass through on the way to the tumor will also be destroyed. At lower intensities the rays are harmless to healthy tissue, but they will not affect the tumor either. What type of procedure might be used to destroy the tumor with the rays, and at the same time avoid destroying the healthy tissue? (taken from Gick & Holyoak, 1983, p.3).

As may or may not be obvious, the story about the general is analogous to the tumor problem. That is, the solution that the general used, to split the army into small forces and send those small forces along different paths so that they converge on the fortress, can be adapted to fit the problem of the tumor. Several weaker rays can be directed through different parts of the body so that they converge on the tumor, creating a force strong enough to destroy the tumor, yet leaving the healthy tissue in tact.
One of the most common, and still most amazing findings in the literature on analogical problem solving is how few people are actually able to appropriately use the solution procedure from the story about the general to solve the tumor problem. Only about 30% of participants are able to spontaneously produce what is called the “convergence solution,” to the tumor problem without the benefit of a hint to do so (Catrambone & Holyoak, 1989; Gick & Holyoak, 1980; 1983; Holyoak & Koh, 1987). This finding is not limited to the two analogous problems presented above. The inability to use information encountered in one situation to understand or solve a problem in another situation is a surprisingly common phenomenon and has been observed in the laboratory (Clement & Gentner, 1991; Gick & Holyoak, 1980,1983; Holyoak, Junn, & Billman, 1984; Novick & Holyoak, 1991; Ross, 1987; 1989a; Ross & Kennedy, 1990), educational settings, (Bassok, 1990; Bassok & Holyoak, 1989; Butterfield & Nelson, 1989, 1991; Perkins & Salomon, 1988; Salomon & Perkins, 1987, 1989) and job training situations (Baldwin & Ford, 1988; Cormier, 1987; Fong, Lurigio, & Stalans, 1990; Smith, Ford, & Kozlowski, 1997).

That transfer seems so difficult a task is problematic. We send our children to school with the intention that they will learn something that can be used later in life. People continue on to postsecondary education to develop an expertise in some chosen field in order to help them get a better job. We train employees so that they will behave on the job in a manner that will benefit the company. If people have such a difficult time transferring information from one situation to a similar yet nonidentical situation, the rationale for all of the education and training we attain seems somewhat weaker. After all, why go to all of the trouble if we can’t demonstrate that we’ve learned anything except on exams?

Numerous manipulations have been attempted in the laboratory that were intended to increase transfer on tasks such as the general and tumor problems mentioned above. Several such manipulations have been somewhat successful, but that success is limited. One strategy has been to give participants generic hints about the relevance of the source story (e.g., the general story) to the target problem (e.g., the tumor problem).
Typically, participants are given an opportunity to solve the target. Once an attempt has been made, they are then told something like, “the first story you read might give you some hints about how to solve this problem” (Gick & Holyoak, 1980, p. 334). Prior to a hint, spontaneous transfer hovers around 30%, but after a hint to use the general problem 75% of participants then offer the convergence solution to the tumor problem (Catrambone & Holyoak, 1989; Gick & Holyoak, 1980, 1983; Holyoak & Koh, 1987).

A second manipulation has been to alter the surface and structural features of the source and the target, making them more or less similar to one another. By increasing the similarity between the two tasks, the likelihood that the target will act as a retrieval cue for the source is increased (Cormier, 1987; Forbus, Gentner, & Law, 1994; Gentner, Ratterman, & Forbus, 1993; Gick & Holyoak, 1987; Holyoak & Koh, 1987; Keane, 1987; Ross, 1987, 1989a, 1989b; Wharton, Holyoak, Downing, Lange, Wickens, & Melz, 1994; Wharton, Holyoak, & Lange, 1996). Two situations can be similar with regards to either their surface features or their structural features (or both). Surface features are considered to be unimportant with respect to the solution procedure. That is, alteration of such features does not change the way the problem is solved. For example, the fact that the source convergence analogue above is concerned with a general and an army does not impact the actual utility of the convergence solution. The fact that the target analogue is concerned with a tumor and X-rays does not change the instantiation of the convergence solution. The solution procedure in each of these two problems is the same and can be represented in an abstract form (see, e.g., Gick & Holyoak, 1983).

Structural features, on the other hand, are aspects of a problem or situation that do alter the solution procedure. For example, if the tumor in the above problem was operable, then the convergence solution would no longer be required. Similarly, if the fortress in the general problem could only be accessed using one road instead of many, the deployment of many small forces from different directions would no longer be a feasible solution.
In general, it has been found that when problems share more surface features, transfer from one to the other is more likely, even if the two differ with respect to structural features. In other words, participants will tend to inappropriately apply a solution procedure to a structurally dissimilar problem when that target problem "looks" the same, or shares surface features with the source (Ross, 1987, 1989a). This finding of an adverse, or negative transfer effect is certainly not new to the literature, as Gestalt psychologists spent time in the middle part of the century studying what were called "set" or "einstellung" effects (e.g., Luchins & Luchins, 1941, 1950). However, when problems share both surface and structural features, transfer is the most likely (Gentner, 1983, 1989; Gentner & Markman, 1997; Gentner, Ratterman, & Forbus, 1993; Holyoak & Koh, 1987; Keane, 1987; Ross, 1987, 1989a, 1989b).

A third manipulation that has been examined quite a lot, and with some success, has been that of schema induction. Typically, participants read not one, but two or more source stories. After summarizing each, participants then compare the two, indicating how they are similar and how they are different. After this comparison, or schema induction, participants are given the target problem to solve. When the target is presented immediately after the schema induction process, transfer rates are quite high relative to a no-schema induction condition (e.g., 45% v. 21%, Gick & Holyoak, Experiment 4; see also Catrambone & Holyoak, 1989; Fong, Krantz, & Nisbett, 1986; Gick & Patterson, 1992; see also Ross & Kennedy, 1990 for a related set of experiments). Interestingly, if the presentation of the target is delayed by as little as 30 minutes, rates of transfer drop back down to non-schema induction levels (Catrambone & Holyoak, 1989). Regardless of the delay, the quality of the comparison participants write out, or the quality of the schema they induce, is predictive of the likelihood of transfer.

Despite the success of the above manipulations, it still seems apparent that transfer is a difficult task. While the above manipulations hold some promise, there is one fundamental problem with their approach that undermines the generalizability of the results to real world situations. That fundamental problem is the fact that in all of the
literature to date, the manipulations have been under the control of the experimenter. That is, an experimenter gave participants hints to use the source story. An experimenter manipulated the surface and structural similarity between the source and the target. An experimenter provided multiple source analogues and provided directions to induce schemas to the participants. In no experiment was the transfer process completely under the control of the subject.

After training or education, there are many situations where people must transfer knowledge without an experienced guide to help them. The resource in the real world that corresponds to the experimenter in the literature is no longer available to the student. The instructor cannot manipulate the similarity of the real world transfer situation to the way the material was presented in class because she cannot foresee all possible events her students will experience. Likewise, the instructor generally is not available to provide hints to her former students when an applicable situation arises.

This having been said, how does transfer occur when it does occur? That is, what are some of the environmental or contextual factors that increase the likelihood that spontaneous positive transfer will occur? As mentioned previously, one thing that has been well documented in several literatures is the fact that the more similar the source and target are, the more likely it is that the source will be used to understand or solve the target (Bassok, 1990; Cormier, 1987; Fong & Nisbett, 1991; Forbus, et al., 1994; Gentner & Markman, 1997; Gentner, Ratterman, & Forbus, 1993; Gentner & Toupin, 1986; Gick & Holyoak, 1987; Holyoak & Koh, 1987; Novick, 1988; Ross, 1987, 1989a, 1989b; Wharton, et al., 1994, 1996). Therefore, intradomain transfer is much more common than interdomain transfer. Similarly, structural similarity increases the likelihood that the transfer will be appropriate. If two problems share surface features but are structurally dissimilar, transfer may occur, but the information transferred is most likely not appropriate for the target situation or problem (Gentner, 1983, 1989; Gentner & Markman, 1997; Novick, 1988). Basically, a solution will be applied to the problem based not on the kind of problem it is, but based on the cover story surrounding the problem.
Existing research on transfer can be classified in terms of when the manipulations occur: at time 1, during the processing of the source, or at time 2, during processing of the target. Many of the manipulations mentioned earlier either address the transfer problem via intervention at time 1, (e.g., schema induction) or via interventions aimed at the interaction between time 1 and time 2, (e.g., manipulation of surface and structural similarity). The only manipulation occurring solely at time 2 is the provision of hints to use the solution procedure from the source. While the various versions of this latter manipulation have produced large increases in the rates of transfer (Gick & Holyoak, 1980, 1983; Catrambone & Holyoak, 1989), both alone and in conjunction with other manipulations, and even after delays of as long as 1 week, this manipulation seems to have the least potential for application to real-world problems. That is, schema induction is something instructors or job trainers can use in their teaching methods by giving students a variety of examples and having them note similarities and differences. Likewise, altering the similarity between surface and structural features of the source and potential targets can be done to an extent by the instructor if common applications of the source material are known. However, when the training or schooling is completed, the instructor is no longer around to point out the relevance of previously learned information to current situations, which is exactly how the hint manipulation works.

This is not to say that interventions occurring exclusively at time 2 are useless. Quite the contrary; it is arguable that such manipulations could be the most effective, if the proper ones were devised. One of the primary bottlenecks in the transfer process is noticing the relevance of prior information to the current situation (Forbus, Gentner, & Law, 1994; Keane, 1987; Ross, 1987, 1989a, 1989b; Wharton, et al., 1994, 1996). The prior information, by definition, has already been learned which prevents the application of any time 1 interventions. However, for some reason, that information is not being cued from memory by the current situation. Therefore, an intervention from someone available at time 2 (e.g., oneself or a supervisor), when the noticing bottleneck is transpiring, could increase transfer rates. In other words, an intervention instantiated in the context in which the target problem is presented could yield useful
results. One such intervention could be in the form of feedback about the appropriateness or feasibility of the original solution proposal.

Presumably, when we encounter problems, we attempt to solve them. We may consider alternative solutions, and advantages and disadvantages of these alternatives. We may or may not consider the constraints involved in the problem. We may or may not ask the opinions of others. However, regardless of the process we use to initially find a solution, we will usually receive feedback on the efficacy of that solution. For example, we may see that a spouse becomes more rather than less angry with our preferred approach to a problem, we may find that driving rapidly on wet blacktop makes the car fishtail, or we may find that our initial approach to a mathematics problem does not yield the correct answer. Feedback, especially if it indicates that the original solution was ineffective, could then prompt a reevaluation of the initial solution and original solution alternatives, which could in turn lead to a different solution procedure incorporating positive transfer. Essentially, when a solution is deemed ineffective via some form of feedback, it indicates that some kind of constraint present in the problem has been violated.

The inclusion of some kind of feedback mechanism with the types of transfer problems used in the literature could allow participants the opportunity to reevaluate their initially proposed, faulty solutions to the target problem. Such a mechanism is an intervention that occurs exclusively at time 2, thereby addressing the potential problems of interventions occurring at time 1. If the feedback mechanism is simple enough, it could be a skill that is easily taught to students. In this manner, students could gain full control over the problem solving process, instead of being partially reliant on the experimenter / instructor when attempting to construct a solution.

Throughout the literature briefly reviewed above, none of the manipulations have included a feedback mechanism. Participants have been given hints, they have been directed to induce schemas and they have been asked very directive questions about the nature of the problems when inducing these schemas. The manipulation that is closest to the idea of feedback about the effectiveness of a solution is the general hints that have
been given after an initial solution attempt. However, participants were not actually told if their proposed solution was valuable or not. Rather, they were told directly that the source story could be of some use with the current problem, effectively giving participants the solution. This manipulation is clearly not applicable to most real-world situations.

Instead of actually pointing out to participants the usefulness of the source problem the following experiments attempt to increase transfer rates by providing a mechanism for direct feedback on how well the proposed solution fits the constraints of the problem. The feedback mechanism was focused on such a constraint analysis because pilot work using the radiation problem and its analogues demonstrated that solutions offered by the majority of participants (approximately 95%) violated constraints stated either explicitly or implicitly in the problem. For example, the radiation problem specifies that the tumor is inoperable. However, in a pilot experiment, 25% of participants explicitly suggested surgery in one form or another as a solution. An example of the violation of an implied constraint noted in the pilot data occurred when participants proposed impossible solutions. Several participants suggested that the surgeon should pass low-intensity rays through the healthy tissue so as to avoid damage. Then once the rays reached the tumor, the surgeon should increase the intensity of the rays. Such solutions demonstrate a basic lack of understanding about the nature of electromagnetic radiation and therefore violate an implicit problem constraint.

In Experiment 1, participants experienced some form of evaluative feedback. In several conditions, an experimenter provided an evaluation of the efficacy of participants' solutions in terms of the problem constraints. Because such evaluations do not directly indicate the usefulness of the source, this form of feedback is more reflective of real-world feedback.

In several other conditions in the first experiment, and in the second experiment, participants were asked to evaluate constraint violations on their own, with only a minimal prompt from the experimenter to do so. Experimenter-provided feedback about
the fit of the proposed solution to the problem may be of some help. However, this feedback is coming from an external source, such as an experimenter. While problem solving situations will most often provide some feedback to the thinker, perhaps a better way to encourage the use of prior information is to help the participants to somehow evaluate the proposed solution for themselves. In prompting self-feedback for a solution, metacognitive processes are activated in that participants are required to think about their solutions and the reasons for those solutions. Therefore, participants in the self-feedback conditions were asked to reread the target problem and then to indicate what kinds of constraints are present in the aquarium problem. After this self-feedback, which was written, participants were then asked to solve the aquarium problem again.
Experiment 1

Method

Participants
Participants were 445 undergraduate Psychology students. They received extra course credit for their participation.

Materials and Design
This experiment was a 3 (no feedback, experimenter-provided feedback, self-feedback) x 2 (schema induction, no schema induction) x 2 (delay in between source presentation and target, no delay) between participants factorial design, which is illustrated in Figure 1. Participants were randomly assigned to one of the twelve resulting conditions, with a total of 25 participants contributing to each condition.

Schema Induction

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<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>No Feedback</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimenter provided</td>
<td></td>
<td></td>
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<tr>
<td>Self provided</td>
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Figure 1. Design of Experiment 1
The schema induction manipulation was included in order to address the issue of experimenter control and in an attempt to replicate previous findings in the literature.

1It is important to note at this point that participants will be given two attempts to solve the target problem. Any participant that provides the convergence solution on the first attempt was not included in the final count of 25 participants per cell—rather the 25 participants in each cell are 25 participants that did not provide the convergence solution on the first attempt.
Previously, participants have been more likely to transfer information when they were prompted to induce a schema prior to an attempt to solve a target problem. Likewise, the delay manipulation was included in an attempt to replicate previous findings that transfer rates decline after a delay as short as 30 minutes (Catrambone & Holyoak, 1989), and in order to protect against possible ceiling effects in the schema induction / no delay / feedback condition and in the schema induction/ no delay / self feedback condition.

The materials used were several of the isomorphs of Duncker’s (1945) radiation problem that have been previously used in the literature (Catrambone & Holyoak, 1989; Gick & Holyoak, 1980, 1983; Gick & Patterson, 1992; Novick & Holyoak, 1991). The radiation problem and the general story, one of the isomorphs, were discussed above. The aquarium problem is as follows:

A major aquarium in a city on the East Coast decided to create a large aquarium display containing a replica of the sunken ocean liner the Titanic amid the sea environment of its resting place, which is deep in the Atlantic Ocean off the coast of Newfoundland. A professional aquarium designer was assigned to the project. She placed a small replica of the vessel in the center of a large tank, with a realistic sea bed. Then she added to the tank sea plants and fish of the sort that live in the Atlantic at the depth of the sunken Titanic. The display was virtually finished with the designer was confronted with a major problem she had failed to anticipate. In order to maintain the deep-water environment required by the fish and plants, the tank had to be kept quite dark, as the deep-water organisms were not adapted to light. However, if the tank was kept completely dark, people would not be able to see the small replica of the Titanic in the center of the tank, which, after all, was the main point of the exhibit. Putting lights inside the model of the wreck looked too artificial. The designer considered shining a powerful spotlight on the model of the vessel. However, if the spotlight was located inside the tank, it would raise the temperature of the water too high; and if it was located outside the tank, the bright beam seriously disrupted the feeding habits of some fish. So, it looked like the display was going to have an embarrassing shortcoming. What could be done to light the display? (Taken from Catrambone & Holyoak, 1989, Appendix C).

The proportion of participants in each condition who transfer the solution from the source to the target was the primary dependent variable.

Duncker’s radiation problem was not used as the target analogue because there have been so many technological advances regarding the treatment of cancer (e.g., the use of X-rays, lasers, and ultrasound) that participants may be less able to produce the
convergence solution because of their knowledge of such technologies. For example, one of the alternative solutions to the tumor problem given in pilot studies was to inject the surrounding tissue with something to protect it from the harmful rays. A then-recent news story discussed a new technology for radiation therapy that did just that—protected healthy tissue surrounding a tumor from radiation therapy. Rather than risk such alternatives decreasing transfer rates, the radiation problem was used as a source analogue. The aquarium problem, originally used by Catrambone and Holyoak (1989) served as the target problem.

The use of the aquarium problem requires that a comparison between rates of transfer in earlier work and rates of transfer in the current study. The design of the current experiment allowed for such comparisons to be made. Specifically, the no feedback, schema induction, no delay condition replicates several of Gick and Holyoak’s (1983) conditions, and the no feedback, no schema induction conditions with either a delay or without a delay replicate conditions in Catrambone and Holyoak’s (1989) Experiments 2 and 3. In this way, it will be possible to see if the results of previous studies are replicable even though a different target problem is being used.

Procedure

The procedures followed as closely as possible those used by Holyoak and his colleagues (Catrambone & Holyoak, 1989; Gick & Holyoak, 1980, 1983). Participants were tested in groups of as many as 15. Upon arrival, participants gave informed consent. They were told that they were participating in an experiment on reading comprehension and problem solving. All participants were then given two of the isomorphic problems: the general story and the radiation problem with appropriate versions of the convergence solution included. In addition, participants were given a folder with answer sheets for the various stages of the experiment. Participants were told to not look into the folders until they were instructed to do so. Except where otherwise noted, each answer sheet was collected from participants as soon as they were finished.
After reading the two source stories, participants were given 10 minutes to summarize each and to rate each on understandability. At this point, half of the participants, those in the no schema induction conditions, were asked to summarize the two stories again without the stories in front of them. This was to ensure that the total amount of processing time was equal between the schema induction and no schema induction groups (see Catrambone & Holyoak, 1989, Experiment 2). Participants in the schema induction conditions were asked to “describe as clearly as possible the ways in which the situations in the two stories seem similar” without the stories in front of them (Catrambone & Holyoak, 1989, Experiment 1, p. 1149). The second summary or schema induction did not take longer than 10 minutes. After the second summary or comparison, participants in the no delay conditions then received the aquarium problem to read and were asked to offer a solution. Participants in the delay conditions, however, received a sheet of multiple-term arithmetic problems and were given 20 minutes to work on this sheet. No participants completed the sheet in the time allotted. After this delay, those participants received the aquarium problem, and were asked to offer a solution.

After offering a solution to the aquarium problem, participants in the no feedback conditions read the final instruction, “You now have the opportunity to revise or change your solution in the next 15 minutes. Please work for the entire 15 minutes.” They were allowed to use the aquarium problem during this second solution attempt, and were required to remain in their seats for the entire 15 minutes. Participants that were in the experimenter-provided feedback conditions were given an evaluation of their first solution prior to offering a second solution. The exact nature of the feedback procedure is detailed below. This evaluation did not include any reference to the source analogues, nor did it in any way implicate the convergence solution. Participants in the self-feedback conditions were given 10 minutes to list the constraints of the aquarium problem after their first solution attempt and prior to their second solution attempt. The exact nature of this manipulation is also detailed below.
Following feedback of either type, participants in these conditions were given the 15 minute revision time, after which they were thanked, debriefed, and dismissed. For both of these conditions, participants were not allowed to keep their first solution attempts, but they were allowed to keep the list of constraints and the aquarium problem during their second solution attempt. The entire experiment lasted from between 45 minutes to 1 1/2 hours, depending on the condition and the speed at which the participants worked.

**Experimenter feedback manipulation.** As mentioned above, participants in the feedback condition had their first solution proposals evaluated in detail by the experimenter. This feedback took the form of identifying the constraints present in the aquarium problem. For example, one line in the story states that, overall, the tank needs to be kept dark because the plants and other organisms are not adapted to light. Any suggestions to place a light at the top of the aquarium will violate this constraint. Similarly, suggestions to use fish adapted to the light will violate the constraint of producing an exhibition of the Titanic in its deep-water resting place.

The experimenter read each participant's first solution and, using the constraints worksheet in Appendix, indicated which of the constraints participants violated and which ones were not violated. Each participant was then instructed to look over this list of constraints and wait for the next set of instructions. Participants were explicitly told about constraints they did not violate in an attempt to prevent such violations on the second solution attempt.

Occasionally, participants proposed solutions that were potentially problematic in terms of the constraints of the problem, but were not in violation of an explicitly stated constraint. For example, some participants suggested that the designer use black lights instead of regular white light. Because one of the considerations of the designer was to make the replica realistic, participants in the feedback conditions who proposed this solution were told, via writing on the constraints list, that black lights might also be unrealistic. The resulting list of constraints along with indications of which ones the subject violated was given to the participant for use during the second solution attempt.
**Self Feedback manipulation.** After the participants in the self-feedback conditions provided their first solution attempt, they were given a second set of instructions prompting them to list the constraints of the aquarium problem. Specifically, they were instructed,

"Please reread the story about the Titanic exhibit. In order for the aquarium designer to come up with a way to make the exhibit satisfactory, she has to overcome several problems. Please list each of these problems. Be as specific as possible."

This instruction was basically the same instruction given to participants in the experimenter provided feedback conditions as an explanation of the constraints worksheet. After participants completed their lists, they were asked to offer an additional solution to the aquarium problem. They were allowed to keep their list of constraints along with a copy of the aquarium problem with them during this phase of the experiment. Finally, as with all other conditions, participants were given a total of 15 minutes to work on this new solution, and were required to sit for the entire time.

**Results**

All data for the current experiment is displayed in Table 1. Several smaller tables and figures will also be presented to highlight certain aspects of the data. A note of caution is in order before the presentation of specific statistical tests. The majority of the statistical tests used in the analysis of this data were chi-square statistics. When computing a chi square, a comparison is made between observed frequencies for each condition and expected frequencies for each condition. As a general rule, when 20% or more of the cells have expected frequencies below 5, the validity of the statistical test become questionable (Freund & Wilson, 1997; Ott, 1993) in that the chi-square distribution may no longer be adequately approximated by the data. However, recent research indicates that despite numerous cells with low expected frequencies, the chi-square distribution is still adequately approximated by the data in some cases (LaMotte, 1999), although the exact conditions under which this is true are not yet fully understood. Therefore, in the current study, when the majority of the cells have
Table 1. Data for Experiment 1

<table>
<thead>
<tr>
<th>Experimental Variables</th>
<th>Source Analysis:</th>
<th>First Solution D.V.s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Schema Quality(^a)</td>
<td>Transfer frequency(^b)</td>
</tr>
<tr>
<td><strong>Schema Induction</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No feedback</td>
<td>1.88</td>
<td>9 (34)</td>
</tr>
<tr>
<td>Exp. feedback</td>
<td>2.06</td>
<td>11 (36)</td>
</tr>
<tr>
<td>Self feedback</td>
<td>2.22</td>
<td>16 (41)</td>
</tr>
<tr>
<td>No Delay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No feedback</td>
<td>2.0</td>
<td>12 (37)</td>
</tr>
<tr>
<td>Exp. feedback</td>
<td>2.29</td>
<td>13 (38)</td>
</tr>
<tr>
<td>Self feedback</td>
<td>2.02</td>
<td>18 (43)</td>
</tr>
<tr>
<td><strong>No Schema Induction</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No feedback</td>
<td>6 (31)</td>
<td>2.21 (.48)</td>
</tr>
<tr>
<td>Exp. feedback</td>
<td>18 (43)</td>
<td>2.44 (.54)</td>
</tr>
<tr>
<td>Self feedback</td>
<td>15 (40)</td>
<td>2.38 (.52)</td>
</tr>
<tr>
<td>No Delay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No feedback</td>
<td>6 (31)</td>
<td>2.18 (.62)</td>
</tr>
<tr>
<td>Exp. feedback</td>
<td>9 (34)</td>
<td>2.4 (.47)</td>
</tr>
<tr>
<td>Self feedback</td>
<td>12 (37)</td>
<td>2.38 (.49)</td>
</tr>
</tbody>
</table>

Notes: a. Schema and self-evaluation were recoded as 1 for poor, 2 for intermediate, and 3 for good. The numbers presented represent means. Sample sizes for schema quality are the same as those given in the first attempt transfer frequency column. Sample sizes for self-evaluation quality were always 25.
b. Transfer frequency for the first attempt is the raw number of subjects. Sample sizes are in parentheses.
c. Quality of solution represents a measure of constraint violations. 1 = multiple constraints were violated, 2 = one constraint was violated, and 3 = no constraints violated. Standard deviations are in parentheses.
Table 1 continued.

<table>
<thead>
<tr>
<th>Experimental Variables</th>
<th>Second Solution D.V.s</th>
<th>Transfer frequency&lt;sup&gt;d&lt;/sup&gt;</th>
<th>Quality of solution</th>
<th>Change&lt;sup&gt;e&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Schema Induction</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delay</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No feedback</td>
<td>6</td>
<td>2.34 (.69)</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Exp. feedback</td>
<td>4</td>
<td>2.57 (.43)</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Self feedback</td>
<td>5</td>
<td>2.27 (.51)</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>No Delay</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No feedback</td>
<td>5</td>
<td>2.37 (.73)</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Exp. feedback</td>
<td>5</td>
<td>2.25 (.79)</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Self feedback</td>
<td>6</td>
<td>2.44 (.51)</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td><strong>No Schema Induction</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delay</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No feedback</td>
<td>4</td>
<td>2.21 (.64)</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Exp. feedback</td>
<td>10</td>
<td>2.4 (.49)</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Self feedback</td>
<td>2</td>
<td>2.27 (.38)</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>No Delay</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No feedback</td>
<td>4</td>
<td>2.24 (.47)</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Exp. feedback</td>
<td>3</td>
<td>2.17 (.79)</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Self feedback</td>
<td>4</td>
<td>2.29 (.40)</td>
<td>21</td>
<td></td>
</tr>
</tbody>
</table>

**Notes continued:**

<sup>d</sup> Transfer frequency for the second solution attempt is raw numbers of subjects with proportions in parentheses. Sample sizes were always 25 for the second attempt.
<sup>e</sup> The change variable represents the number of participants out of 25 offering a different solution on the second solution attempt.
expected frequencies below 5, the analyses will not be done. However, when a minority of cells meets this criteria, the analysis will be presented along with a cautionary word.

**Transfer Rates**

The primary dependent measure was the proportion of participants who offered the convergence solution to the aquarium problem. All analyses are separated into those for the first solution attempt and for the second solution attempt.

Previously, only “complete” convergence solutions were counted (Catrambone & Holyoak, 1989; Gick & Holyoak, 1983). That is, participants had to mention multiple smaller rays (for the tumor problem) aiming at the tumor from multiple directions striking the tumor simultaneously in order to be considered a convergence solution. The analogous solution would be multiple smaller lights shining on the replica of the Titanic from different angles simultaneously. “Partial” convergence solutions, on the other hand, were scored in the current experiment as the use of multiple low-intensity lights without explicit reference to the rays shining at the ship. Aside from preventing the possibility of floor effects, the inclusion of partial convergence solutions was also deemed important in order to guarantee that no one who had transferred on the first solution attempt was included in the second attempt analyses.

In order to make sure that the addition of partial solutions did not alter the distribution of convergence solutions across conditions, several analyses were conducted. Specifically, four chi square tests were run to test the hypotheses that the distributions of either partial or complete convergence solutions did not differ across conditions for either first or second solution attempts. The only nonhomogeneous distribution found was for the second try of partial convergence solutions ($G^2 (2) = 5.02, p = .08$). This significant result indicates that there was a difference in transfer rates across the 12 conditions. However, four of the cells had observed frequencies of 0, and half of the cells had expected frequencies of less than 5. Over all 12 conditions, there were only 23 partial convergence solutions given on the second attempt, so this result should be viewed with skepticism.
First solution attempt. In past literature, there has been an interaction between schema induction and delay such that the advantages of schema induction seem to disappear after a 30-minute delay has been imposed between source and target exposure (Catrambone & Holyoak, 1989). Collapsing across feedback conditions (because participants did not receive feedback until after their first attempt), the interaction between schema induction and delay was marginally reliable ($G^2 (1) =2.64, p = .1$). These data are illustrated in Figure 2.

![Figure 2. Proportion of convergence solutions on 1st solution attempt collapsing across feedback condition](image)

Second solution attempt. The data for the second solution attempt are illustrated in Figure 3. Using a chi-square analysis, the hypothesis that the frequencies across all of the groups are the same was tested. The difference between the twelve groups was not statistically reliable ($G^2(2) = .26, p=.88$), indicating that there was not an interaction between the schema, delay, and feedback manipulations. The difference
between the three feedback conditions without consideration of the schema induction or delay variables was also not statistically reliable, \(G^2(2) < 1.0\). Consideration of the schema induction and delay variables only did not yield the same interaction observed in the first attempt data, \(G^2(1) < 1.0\).

![Figure 3. Proportion of convergence solutions on 2nd attempt as a function of schema induction, delay, and feedback condition](image)

**Schema Quality**

In addition to the proportion of participants providing the convergence solution to the aquarium problem, some participants also provided comparisons between the two source analogues. Previously in the literature (Catrambone & Holyoak, 1989; Gick & Holyoak, 1983), it has been assumed that these comparisons reflect the quality of the abstract representation, or schema, that participants have induced about the problem. Therefore, schema quality should predict the likelihood that a given participant will
transfer the convergence solution. The schema in the current study were coded for different levels of quality according to the following criteria:

**Good** - A schema was rated as good if it included at least two of the following ideas: that forces converged on different directions simultaneously, the use of multiple smaller forces, or other parallels between the two situations (e.g., centrally located targets) that are directly relevant to the convergence solution. Participants rarely mentioned similarities other than the first two above. An example of a good schema would be, “in both stories, the hero had to divide up his large force into multiple smaller forces to attack the centrally located target and destroy it.”

**Intermediate** - An intermediate schema contained only one of the above ideas. An example of an intermediate schema is, “Both the general and the doctor had to divide a large force into multiple smaller forces to destroy the target.”

**Poor** - a poor schema contained none of the basic aspects of the convergence problem.

These data were analyzed in an attempt to see if schema quality was predictive of transfer, as it has been in previous work (Catrambone & Holyoak, 1989; Gick & Holyoak, 1983). As with transfer rates, the first solution attempt and second solution attempt data were analyzed separately.

Combining data from the feedback conditions for both first and second solution attempt, these data were analyzed using a chi-square test of independence. Schema quality did reliably predict first attempt transfer rates ($G^2(2) = 16.41, p = .001$). This trend also appeared with the second solution attempt, although the chi-square was only reliable at the 10% level ($G^2(2) = 5.34$). These data are illustrated in Figures 4a and 4b.

**Self Feedback Quality**

Participants in the self-feedback conditions provided data for a third dependent variable: quality of problem constraint analysis. This variable was scored according to the number of constraints the participants identified. The list of constraints in the Appendix was used to develop a scale to rate self feedback as being of good,
intermediate, or poor quality. A self feedback protocol was given a rating of good if the participant identified at least 5 of the constraints listed in Appendix A\textsuperscript{2}. A rating of intermediate was given if 3 or 4 were identified, and a rating of poor was given if fewer than 3 constraints were identified. Combining the schema induction and delay variables, self feedback quality was not predictive of transfer, \((G^{2} (2)= 3.15, \ p = .21)\).\textsuperscript{3}

These data are illustrated in Figure 5. While the figure seems to illustrate a relationship, there were only 21 out of 100 participants providing the convergence solution on the second attempt in the self-evaluation conditions, so the lack of statistical significance could be due to low power.

\textsuperscript{2}The first constraint listed in Appendix actually is made up of two requirements of the problem. The first is that the exhibit must have fish and plants in it that live at the Titanic’s resting place. The second constraint is that the majority of the tank must be kept relatively dark. Inclusion of both of these constraints makes 6 the total number of constraints in the aquarium problem.

\textsuperscript{3}Please note that all self-feedback results are only for second solution attempts, because participants had not been exposed to the self-feedback manipulation until after they had offered their first solution.
Ancillary analyses

While none of the hypotheses were supported in the current experiment using transfer rates as the primary dependent measure, there are other ways of looking at the data. One assumption that was used as justification for the current experiments was that if participants are made aware of constraints of the problem, they will be more likely to look elsewhere for a solution, which should increase rates of transfer. Curiously, participants in the current experiment commonly persisted in their violation of the problem constraints, despite the fact that the constraints had either been pointed out to them, or the participants had identified them on their own. Many second-attempt solutions read similarly to, “I know that the aquarium designer wants the exhibit to be as realistic as possible, but she is going to have to sacrifice something, and I think the fish should go. They’re not the point of the exhibit, anyhow.” While many participants did change their second solution (79% proposed a different second solution), in most cases

*An example of a different solution would be if a subject proposed the use of black lights in the first attempt and then proposed moving the Titanic closer to the edge of the aquarium on the second solution attempt.*
Figure 5. Proportion of participants transferring the convergence solution as a function of self feedback quality.

This second solution violated some constraints of the problem just as the original solution did (only 28% of participants violated fewer constraints the second time around, and only 21% of participants provided the convergence solution on the second attempt). To see if there were differences across conditions in the numbers of participants changing their solution or improving their solution, solutions were scored according to the number of constraints they violated, whether or not the solution changed from the first to the second solution attempt, and if the quality of the solution improved from the first to the second solution attempt.

Quality of solutions according to the number of constraints violated. Considering first the quality of the solutions, if the solution violated more than one constraint, it was given a 1. If only one constraint was violated, the solution was given a 2. If the solution did not violate any constraints of the problem it was given a 3. In the event that a participant provided multiple solutions, the highest score was recorded. The average quality of responses, did not differ across conditions for either the first solution attempt ($F (4, 446) = 1.09$, $p = .36$) or the second solution attempt ($F (4, 314)$  

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Looking more closely at the solution quality data for the second solution attempt, it appears that experimenter feedback may increase transfer when there is not a delay whereas self-evaluations may help transfer when there is a delay. Combining the schema induction with the no schema induction conditions, the average quality scores for the experimenter feedback conditions were 2.49 with a delay and 2.21 without a delay. Comparable quality averages for self-feedback conditions were 2.21 with a delay and 2.37 without a delay. An analysis of variance on the raw data did not yield a significant interaction or main effects. In order to reduce the variability present in the data, a log transformation was applied and the analysis of variance repeated. The interaction between feedback (excluding the no feedback condition) and delay was not significant, but there was a marginal main effect for feedback ($F(1, 207) = 3.86$, $p = .051$) indicating that experimenter provided feedback may have an advantage over constraint analysis in the form of self-feedback when the violation of constraints is considered.

Rates of solution change and of solution improvement. In order to ascertain if the rates of change or improvement differed across conditions, two chi-square analyses were conducted. There were no differences in rates of change or rates of improvement as a function of condition ($G^2(2) < 1.0$; $G^2(2) = 1.19$, $p = .55$ respectively). Combining the schema and delay conditions, the rates of change did not differ as a function of feedback condition ($G^2(2) = 3.19$, $p = .2$), nor did the rates of improvement ($G^2(2) = 1.66$, $p = .44$). In addition, neither schema quality nor self feedback quality impacted the rates of change (both $G^2s < 1.0$) or improvement ($G^2(2) < 1.0$; $G^2(2) = 3.64$, $p = .16$ respectively).

Summary and Discussion

Overall, the results of the first study were not as expected. Overall, the current data did not replicate any of the effects reported in the literature except that schema
quality predicted transfer. However, there are some interesting aspects of the data that should be highlighted.

**Rates of Transfer**

**Complete versus partial convergence solutions.** Generally speaking, the rates of transfer in the current experiment are overall consistently lower than those reported in earlier studies. While some of the comparisons to be made later in this section will seem to contradict this statement, the fact that both partial and complete convergence solutions were counted in the current study needs to be kept in mind.

In the current experiment only 97 complete convergence solutions appeared out of a total 754 first and second solutions offered. When one considers the fact that the majority of participants would offer more than one solution per attempt, the number of complete convergence solutions becomes even smaller.

Considering only complete convergence solutions, rates of first attempt transfer in the literature run from 16% (no schema / no delay, first attempt) to 47% (schema induction / no delay, first attempt). In the current experiment, the proportions of complete convergence solutions ranged from 10.5% for the no delay / no schema condition for the first attempt to 13.3% in schema induction / delay condition for the first attempt. When complete and partial solutions are considered the proportions of participants transferring on the first attempt increase to 26% in the no schema / no delay condition and to 36% in the schema induction / no delay condition. In the literature, it is expected that after exposure to a single analogue, rates of spontaneous transfer without a delay will be about 30% (Gick & Holyoak, 1983). So, when both complete and partial convergence solutions are considered, rates of transfer in the current experiment hover around the expected baseline of 30%.

**Rates of transfer as a function of delay and schema induction.** Previous literature (Catrambone & Holyoak, 1989, Experiment 2) demonstrated that a delay imposed in between the presentation of the source and the target eradicated any beneficial effects of schema induction on transfer. The delays imposed have been 30 minutes and 1 week. Both of these delays showed no advantage of schema induction
until after participants had been given an explicit hint to use the source stories (Catrambone & Holyoak, 1989). In the current study, however, there was no effect of schema induction on the likelihood that participants would use the convergence solution on their first solution attempt (see Figure 2). In fact, none of the conditions were above the expected baseline of 30%. The use of a different target problem could be an explanation for this result.

The no schema induction / delay / experimenter feedback condition. A third interesting point regarding transfer rates is the relatively high proportion of second-attempt transfer in the no schema induction / delay / experimenter feedback condition (see Figure 3). It may be that there is something particularly special about the combination of variables in the no schema / delay / experimenter feedback condition. This would mean that either this particular feedback manipulation aided transfer only in the absence of abstract processing via schema induction and with a delay, or that the other two manipulations (i.e., no feedback and self-feedback) greatly hindered transfer. There are several problems with these two possibilities. One problem is that if the experimenter feedback manipulation was that beneficial, one would expect to see some kind of elevation in the other experimenter feedback conditions. However, the other experimenter-feedback conditions hovered around the baseline control of 16% (i.e., 12%, 16%, and 20%).

A second problem with this “special” hypothesis is that one might also expect to see a slight elevation in the analogous self-feedback condition (i.e., no schema / delay / self-evaluation) because the instruction to participants was almost identical in these two conditions, and because the lists of constraints produced by the participants in the self feedback conditions were often very close to the list of constraints used in the experimenter feedback conditions (40% of participants listed all of the constraints presented in the experimenter feedback condition, and 84% of participants listed more than half of these constraints). However, the rate of transfer in the no schema / delay / self feedback condition was below that of the baseline control (8% vs. 16%), although not significantly so ($G^2(1) < 1.0$).
It is important to keep sight of the fact that the test of homogeneity was not even marginally significant. So, the conclusion that must be reached for these data is that the elevation in the no schema / delay / experimenter feedback condition is a chance occurrence until the pattern can be replicated.

**Schema Quality**

In previous literature (Catrambone & Holyoak, 1989; Gick & Holyoak, 1983), schema quality predicted transfer only when the good and intermediate schemas were contrasted with the poor schemas. In these earlier studies, scoring was more strict than in the current experiment in that good schemas had to mention that forces converged from different directions simultaneously along with one other convergence idea (i.e., multiple smaller forces or centrally located target). In this study, however, the good schemas only had to mention two convergence ideas, regardless of which two (e.g., a good schema could read, “in both stories, the hero had to divide his/her single strong force into multiple smaller forces in order to destroy the centrally located target”). This change resulted in more “good” schemas, but seems to have increased the predictive value of schema quality, as there was no need to combine “good” and “intermediate” schemas to find a relationship (cf. Gick & Holyoak, 1983).

**Self feedback**

It was hypothesized that when participants were made aware of the constraints present in a problem they would be more likely to consider alternative options. This, in turn, should increase transfer rates on a second solution attempt after participants were made aware both of the constraints they violated and of the constraints they accounted for. Overall, this hypothesis was not supported, in that there was no main effect of feedback condition. However, it could be that when participants are analyzing the constraints for themselves, the quality of this analysis might be predictive of the likelihood of later transfer. Unfortunately, when combined across delay and schema conditions, the self-feedback variable did not significantly predict second attempt transfer. In light of these nonsignificant results, it is important to note that a greater proportion of participants who produced good feedback were more likely to transfer the
convergence solution than not (see Figure 5). The opposite pattern was observed for those participants producing intermediate and poor feedback. These participants were more likely to suggest solutions other than the convergence solution. This seems contrary to the statistical analysis, which indicated no interaction between these two variables. As stated above, however, these data are based on a very small number of participants (a total of 21 produced the convergence solution on the second solution attempt). Given a much larger sample of people transferring on the second solution attempt, this apparent interaction might be significant.

General comments

As mentioned, the results in the current experiment were not as expected. Actually, there does not appear to have been any control exerted over the transfer phenomenon. Rates of transfer seem fairly stable over conditions, regardless of the inclusion of manipulations that should have had an impact according to the literature (i.e., schema induction, delay). Analysis of the data using alternative dependent variables such as quality of solutions, and rates of change and improvement from first to second solution attempt further corroborate these null findings.
Experiment 2

While there are many questions raised in the first experiment, it is important to replicate some of the results from the first experiment before introducing new manipulations. Therefore, in Experiment 2, two of the conditions from the first experiment appear in concert with three other conditions designed to extend the self feedback manipulation used in the first experiment. In Experiment 1, participants in some conditions were asked to first write out a comparison between the two source analogues, which should help them to induce an abstract representation of the solution procedure (Gick & Holyoak, 1983). Then, participants were asked to offer a solution to the aquarium problem, and subsequently they listed the different constraints of this problem. The assumption made in Experiment 1 was that once participants were made explicitly aware of the boundaries of the problem, they would more likely search for and find alternative solutions, including the convergence solution. In other words, once aware of the constraints placed on possible ways to light the Titanic replica, participants would be more likely to notice the relevance of the source problems to the target and show transfer. However, this prediction was not confirmed.

Participants in Experiment 1 performed constraint analysis only on the target (time 2) and not on the source. Perhaps this was the reason the manipulations failed to enhance transfer. This second experiment manipulated both the schema induction variable and the constraint analysis variable of the source analogues. That is, participants either induced a schema from the two isomorphic source analogues or not, and they either analyzed the constraints of these two problems or not. All participants in Experiment 2 analyzed the constraints of the target problem.

This type of manipulation has an additional advantage over a simple schema induction analysis in that it is easier to teach participants the heuristic of constraint analysis than it is to teach the more complex task of schema induction intuitively seems much easier to teach to people than the skill of schema induction (e.g., Reeves & Wesiberg, 1994; Herrnstein, Nickerson, Sanchez, & Swets, 1986). In addition, constraint analysis can be performed on a single source problem, whereas schema
induction requires two isomorphic source problems, which is, in essence, a separate problem of transfer. In order to perform schema induction on their own, without outside cues, hints, or directions, participants have to notice that one problem is analogous to the other. With constraint analysis, on the other hand, participants can perform such an analysis on a single problem. By analyzing the constraints of that problem, additional information about the problem is encoded. That additional information about the problem may increase the likelihood that its relevance to a future problem is noticed when the constraints of that future problem are analyzed and are the same or are similar. In this way, the problems are being defined not in terms of solutions but in terms of barriers to solutions, which, in turn, suggest what may be nonobvious solutions.

Method

Participants

Participants were 184 undergraduate students in Psychology. Due to experimenter error, data from 16 participants were discarded, creating a new total of 168. They received extra course credit for their voluntary participation.

Materials and Design

The materials used were identical to those used in the previous experiment. This was a 2 (schema induction, no schema induction) x 2 (constraint analysis of source, no constraint analysis of source) between-participants design. A fifth condition, one in which constraints of the source analogue are analyzed, but in which participants only saw one source, was added in order to partial out the effects of participants' exposure to multiple source analogues. Figure 6 illustrates the design of this experiment.

Procedure

Upon arrival, all participants were given a folder with answer sheets and they were given the source problem or problems, depending on the condition. All participants first summarized the source problem or problems. After the summary, participants were asked to do a variety of tasks, depending on the condition.
The 72 participants in the two source constraint analysis conditions (conditions 1 and 2, see Figure 6) were given these instructions,

In order for the people in these two stories to come up with acceptable solutions, there were several problems they each had to overcome. Please reread these stories and list each of these problems as best you can. Please be as specific as possible.

After reading and summarizing the source problems, and after specifying the constraints, participants in the schema induction condition (condition 1) were asked to write a comparison of the two source stories. Participants in the no-schema induction condition (condition 2) were asked to write a second summary of each story.

Participants who were in the no constraint analysis conditions (conditions 3 and 4) were simply asked to write a comparison between the two stories, or were asked to write out a second summary. Conditions 3 and 4 are identical to the no schema / delay / self feedback and to the schema / delay / self feedback conditions in Experiment 1. After the initial summary of the general problem, those participants in the fifth, single source condition were asked to write out the constraints of the general story, and were then asked to summarize this story again.
Following the different procedures during source presentation and processing, all participants then experienced a 20-minute delay during which they solved multiple-term arithmetic problems. They were then given the aquarium problem and asked to offer a solution to it. Finally, all participants were asked to specify the constraints of the aquarium problem in the same manner as Experiment 1, after which they were given 15 minutes to revise their first solution.

**Results.**

All data for the second experiment are displayed in Table 2.

Table 2: Results of Experiment 2.

<table>
<thead>
<tr>
<th>Experimental Variables</th>
<th>Source Analysis:</th>
<th>First Solution D.V.s</th>
<th>Self feedback quality - target</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Schema Quality&lt;sub&gt;a&lt;/sub&gt;</td>
<td>Self feedback&lt;sub&gt;a&lt;/sub&gt;</td>
<td>Transfer frequency&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td><strong>Schema Induction</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source constraint analysis</td>
<td>2.11</td>
<td>2.05</td>
<td>13 (38)</td>
</tr>
<tr>
<td>No source constraint analysis</td>
<td>2.12</td>
<td>9 (34)</td>
<td>2.29 (.72)</td>
</tr>
<tr>
<td><strong>No Schema Induction</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source constraint analysis</td>
<td>2.09</td>
<td>8 (33)</td>
<td>2.27 (.59)</td>
</tr>
<tr>
<td>No source constraint analysis</td>
<td>2.67</td>
<td>5 (30)</td>
<td>2.21 (.53)</td>
</tr>
<tr>
<td><strong>Single Source condition</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Note: a. Schema and self feedback were recoded as 1 for poor, 2 for intermediate, and 3 for good. The numbers presented represent means. Sample sizes for schema quality and self feedback of the source are the same as those given in the first attempt transfer frequency column. Sample sizes for self feedback quality of the target were always 25. b. Transfer frequency for the first attempt is the raw number of subjects. Sample sizes are in parentheses. c. Quality of solution represents a measure of constraint violations. 1=multiple constraints were violated, 2=one constraint was violated, and 3=no constraints violated. Convergence solutions are included in 3-level solutions. Standard deviations are in parentheses.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2 continued

<table>
<thead>
<tr>
<th>Experimental Variables</th>
<th>Transfer frequency&lt;sub&gt;d&lt;/sub&gt;</th>
<th>Quality of solution</th>
<th>Change&lt;sub&gt;c&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Schema Induction</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source constraint analysis</td>
<td>4</td>
<td>2.11 (.81)</td>
<td>20</td>
</tr>
<tr>
<td>No source constraint analysis</td>
<td>7</td>
<td>2.31 (.65)</td>
<td>19</td>
</tr>
<tr>
<td><strong>No Schema Induction</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source constraint analysis</td>
<td>3</td>
<td>2.31 (.4)</td>
<td>24</td>
</tr>
<tr>
<td>No source constraint analysis</td>
<td>2</td>
<td>2.16 (.57)</td>
<td>20</td>
</tr>
<tr>
<td><strong>Single Source condition</strong></td>
<td>2</td>
<td>2.38 (.39)</td>
<td>17</td>
</tr>
</tbody>
</table>

Notes continued:  
<sup>d</sup> Transfer frequency for the second solution attempt is raw numbers of subjects. Sample sizes were always 25 for the second attempt.  
<sup>c</sup> The change variable represents the number of participants out of 25 offering a different solution on the second solution attempt.

**Transfer Rates**

As with Experiment 1, the primary dependent variable was the proportion of participants transferring the convergence solution on first and second solution attempt. These data are illustrated in Figure 7. Rates of transfer did not differ as a function of condition for the first solution attempt ($X^2(4) = 3.157, p > .5$). Rates of transfer on the second solution attempt were relatively low compared to the first transfer rates (across all conditions, there was an average of 3.8 participants transferring the convergence solution), although they were quite similar to second attempt rates in the first experiment. A chi-square statistic indicated that rates of transfer did not differ across
Figure 7. Proportion of participants transferring as a function of condition and solution attempt.

Note. NC represents the no source constraint analysis condition and C represents the source constraint analysis condition. NS stands for a no schema induction condition, whereas S indicates a schema induction condition.

the 5 conditions, \(X^2 (4) = 5.22, p > .25\), however 5 of the 10 cells had expected values below 5, which indicates that the reliability of the test may be compromised.

Schema Induction

Participants in two conditions were also asked to write out a comparison between the two source stories. These schemas were coded for quality in the same manner as outlined in the procedure for Experiment 1. Schema quality was predictive of first attempt transfer \(G^2 (2) = 9.41, p = .009\); however, this relationship was not true for second solution attempt, \(G^2 (2) = 2.2, p = .33\). It is important to note that three of the six cells in this latter analysis had expected values less than 5, and therefore may not be reliable. These data are illustrated in Figures 8a and 8b.
Self Feedback

Participants in all conditions analyzed constraints of the target problem; however, some participants in the current experiment also listed the constraints of the source problem or problems. The scale used to score constraint analyses for the aquarium problem in Experiment 1 was also used with the current data. In addition, this scale was adopted for use with the two source stories. For participants providing analyses of two source stories, the score given reflects analysis of both problems. That scale is as follows. A poor analysis is one in which the participant has identified 2 or fewer constraints. An intermediate- analysis is one in which the participant has identified 3 or 4 constraints from one story. An intermediate+ schema is one in which the participant has identified 3 or 4 constraints, with at least one constraint from each story. A good analysis is one in which the participant identified 5 or 6 constraints.
Overall, the general story was considered to have two constraints:

First, the general needed to use his entire army to overtake the fortress.
Second, if he sent his entire army down one road, mines in the road would detonate, killing the army and destroying surrounding farms and villages.

The tumor story was considered to have four constraints:

A patient has an inoperable tumor
The tumor must be destroyed or the patient will die
Rays of sufficient intensity to kill the tumor will also kill the healthy tissue
Rays of levels safe enough to pass through the healthy tissue will not destroy the tumor

For self feedback of the source, the intermediate - and intermediate + conditions were combined because there was only one intermediate - score. For participants in the single source condition, if they listed both constraints to the general story, it was considered a good analysis. If they listed one constraint, it was considered to be an intermediate
analysis, and if neither of the above constraints was listed, it was considered to be a poor analysis.

Quality of self feedback protocols of the source did not influence first attempt transfer, \( G^2 (2) < 1.0 \), nor did it influence second attempt transfer \( G^2 (2) = 2.2, p = .33 \). The analysis of the second attempt data may not be reliable, however, because expected values in 3 of the 6 cells did not exceed 5. Quality of self feedback of the target reliably impacted likelihood of second attempt transfer, \( G^2 (2) =6.64, p = .036 \). These data are illustrated in Figure 9.

![Figure 9. Proportion of participants transferring the convergence solution as a function of target self feedback quality.](image)

**Solution Quality.**

**Number of constraints violated.** As with the first experiment, the quality of solutions was scored according to the number of constraints that were violated. Analyses of these data yielded only one significant result—an interaction between schema induction and source constraint analysis on the first solution attempt. Schema induction appears to aid solution quality in the absence of source constraint analysis,
while source constraint analysis seems to aid solution quality in the absence of schema induction, \( F(1, 4) = 4.21, p = .042 \). These averages are displayed in column 4 in Table 2.

**Rates of change and improvement.** In addition to the quality of solutions, the rates of change and improvement across conditions were tested, and the groups did not differ with regards to the number of participants changing their solutions \( \chi^2(4) = 6.47, p = .17 \) or in the number of participants improving the quality of their solutions, \( \chi^2(4) = 2.36, p = .67 \).

**Summary and Discussion**

While the results of the current experiment were not as expected, generally, they replicate Experiment 1. The predictive power of schema induction for first attempt transfer (see Figures 4a and 8a), and a marginal effect of self-feedback quality on second attempt transfer (see figures 5 and 9) was replicated from Experiment 1. Rates of transfer in the current experiment are somewhat different from those in Experiment 1, however. As with the first experiment, partial convergence solutions were included in all analyses.

First attempt rates of transfer ranged from 21.8% in the no schema / no source constraint analysis condition to 33% in the schema / source constraint analysis condition. Comparing the identical conditions in the two experiments, the no schema / no source constraint analysis condition in this experiment yielded a transfer rate of 21.8%, whereas the identical condition in Experiment 1 had a transfer rate of 37.5%. Participants in the schema / no source constraint analysis condition in the current experiment produced the convergence solution 26.5% of the time, while participants in the identical condition in Experiment 1 produced the convergence solution 39% of the time.

To put these numbers into perspective with the literature, comparable percentages from the literature are 10% in a no schema / 30-minute delay condition and 53% in a “more directive” comparison (of source problems) condition (Catrambone & Holyoak, 1989, Experiment 4). So, even though the rates in Experiment 1 are higher...
than Experiment 2, they are still quite different from those found in the literature, and they still seem to hover around that expected baseline of 30%. Therefore, the ineffectiveness of the current manipulations was replicated in Experiment 2.

There was an interesting schema induction by constraint analysis of source interaction that was significant. The analogous analysis from Experiment 1, schema induction by feedback (excluding experimenter feedback condition) was not statistically significant. This finding for Experiment 1 is not terrifically surprising, however, as the interaction in Experiment 2 is between two time 1 manipulations (i.e., source constraint analysis and schema induction all happen at the presentation of the source analogues), whereas the schema induction by feedback interaction for Experiment 1 would be an interaction between a time 1 manipulation and a time 2 manipulation—that is schema induction occurs at the presentation of the source whereas constraint analysis in Experiment 1 occurred after the presentation of the target. Also, as schema induction had no effect on the probability of second attempt transfer, one would not expect this variable to then interact with a manipulation applied directly to the target problem. Self feedback of the target did not itself impact second attempt transfer.
General Discussion

Generally the variables manipulated in the current experiments did not exert any control over participants’ abilities to utilize the convergence solution when asked to solve the aquarium problem. Even results that have seemed fairly robust in the literature (e.g., the effectiveness of schema induction) were not replicated. Several dependent measures, all designed to evaluate the effectiveness of the manipulations, indicated that the manipulations had no effect. As will be discussed in more detail later, there was one difference in the materials used for the current experiments which may have had a significant impact on transfer rates: a different target problem was used. The fact that the literature was not replicated with a different version of the same kind of problem commonly used in addition to the multiple dependent measures all showing no effect both highlight the fragility of the phenomenon and bolster the point that science really doesn’t know what reliably aids transfer.

Another primary reason for these null results could be a lack of power. However, these results are based on responses from 613 undergraduates. Further, these experiments had 25 participants per cell for the second solution attempt and anywhere from 30 to 43 participants per cell for the first solution attempt. By way of comparison, Holyoak and his colleagues (Catrambone & Holyoak, 1989; Gick & Holyoak, 1980, 1983) averaged 21.14 participants per cell over 42 samples. Therefore, the sample sizes in the current experiment should be adequate for detecting differences of the magnitude reported in the literature.

There are several other possible explanations for the ineffectiveness of the current manipulations that do not discount the underlying justification for those manipulations. The majority of these explanations have to do with the nature of the task and with specific characteristics of the manipulations, and are detailed below.

Problems With the Nature of the Task

There are several important methodological aspects of the convergence task that has been used in previous literature and in the current study that may be hindering transfer. First, the way in which the source and target problems are presented may
create difficulty. The convergence problems are very spatial problems and having subjects read a paragraph or two might not be sufficient to provide an understanding of the solution; the essence of which is contained in a spatial relationship. Relatedly, it may be that the brief exposure to two exemplars of these problems may not be sufficient to allow participants to "learn" the class of convergence problems. Third, there could be a problem with the kind of feedback presented to participants in that it is concrete and nonexperiential. Fourth, there might simply be a difficulty with the class of convergence problems in that the convergence solution may not always be the best solution.

Presentation of the Source Problems

The method of presenting the source and target problems could have an impact on transfer behavior. The problems used in this and other studies are very spatial problems. For example, the general splits his army into several smaller forces and sends them all down separate roads to converge on a centrally located target. The essence of the solution—that which makes it the convergence solution, is contained within the spatial relationships between the separate smaller forces and the centrally located target. The tumor problem and aquarium problem are no different.

However, the way in which these situations are presented to participants is verbally, written on a piece of paper. Participants are asked to write out their solutions, rather than to present their solutions in a configural manner, or to actually manipulate the aquarium materials for themselves. It could be that if the source stories were presented visually (e.g., a short videotape of the general showing how he plans to split up his army to his troops using a map and army men) rather than verbally, and if the measure of transfer was more performance-based (e.g., participants actually manipulate a real aquarium), we might find that people are not as bad at transfer in general as they seem to be with the kinds of tasks used in the literature (cf. Holyoak & Thagard, 1995; 1997). Alternatively, a researcher could provide participants with drawings of the source solutions (see, e.g., Gick & Holyoak, 1983), or could require participants to produce these diagrams. In requiring participants to produce diagrams of the source problems,
participants would be required to consider the aspect of the solution that makes it as effective, which may be more appropriate for convergence problems than the written summary or even written schema induction.

**Learning the Class of Convergence Problems**

In order to transfer information, one must first learn that information. How well did participants learn the convergence solution? One of the assumptions of schema induction is that if a participant has induced a good-quality schema, that person has developed an abstracted version of the convergence solution (Gick & Holyoak, 1983). Interestingly, in prior research (Catrambone & Holyoak, 1989) the effects of this schema induction disappear as rapidly as 20 to 30 min. Can we say that the participants have really learned the convergence solution if the effects disappear so soon? Some scientists believe that learning is evidenced when you see a change in behavior (Dougher, 1993). If the change in behavior only lasts 20 minutes, is that really evidence of learning?

One of the most generally agreed-upon statements about transfer is that transfer is dependent on the structural features of the problem. Generally, experts, people who really know the information, are able to attend to the structural features of the problem, which allows them to apply a given solution or other ideas to a relatively wide range of situations within that domain. In essence, experts have induced schemas, or abstract representations of different problems or situation classes (cf. Gick & Holyoak, 1983; Novick, 1988). Novices, on the other hand, tend to pay more attention to the surface features of the problem at the expense of the structure. In essence, they have failed to induce a schema.

These studies are looking for cross-domain transfer by novices. Perhaps, inducing such schemas that will transfer across domains takes more than to summaries of a couple of short stories. For example, if participants were taught the “class” of convergence (or other) problems with a couple of examples from several domains and were given training identifying examples in now domains, then transfer rates might be improved. Further, such effects might last longer than 30 minutes. At this point, we do
not know how many different examples of a problem type a learner needs to experience before she can reliably differentiate between another example and a "foil" problem with similar surface features (cf. Butterfield & Nelson, 1989; Ross & Kennedy, 1990).

**Form of Feedback Manipulation**

As mentioned in the introduction, the way in which problem-solving transfer has been studied to date seems somewhat artificial. Specifically, this point was made in order to argue the importance of feedback in a problem solving situation, and was used to justify the inclusion of the various constraint analysis manipulations in the current experiments. While the presence of feedback arguably makes the current experiments more ecologically valid than previous studies, just how ecologically valid the current experiments are is still questionable.

The constraint analysis manipulations in the current experiments are straightforward forms of verbal feedback. Participants were made explicitly aware of the constraints in the problem and whether or not their original solution addressed these constraints. Comparison of each constraint with the proposed initial solution was most explicit in the experimenter feedback conditions. yet, this form of feedback had no impact on participants' behavior. Not only was there no change in transfer rates, but there was also no change in the quality of second solutions provided. There are a couple of possible reasons for this:

Experiential feedback is often an intrinsic part of the problem solving situation. For example, if you are driving too fast on wet pavement and try to turn the wheel of your car, you may begin to slide because of hydroplaning. This slide is a form of feedback that is intrinsic in the situation. It is an effect that is experienced which has a cause coming directly from the situation. It is an effect that you experience as a direct result of your actions. It could be that there is a difference between the kinds of feedback presented in the hydroplaning example and the kind of feedback given to participants via constraint analysis. That is, in the current experiments, participants never actually experienced the consequences of their proposed situations. Rather, they proposed solutions, were told (in one form or another) that their solutions wouldn't
work for any number of reasons, and then were asked to write out another solution. Participants who proposed the use of black lights on the replica never experienced how artificial it looked. Participants who proposed taking out the fish never experienced the boss's displeasure at the lack of deep-water flora. Participants who proposed having the room be light without any lights shining on the aquarium never actually tried to look into a very dark aquarium. Maybe the element essential for a feedback manipulation to have an effect is an experiential component that the current manipulations lacked.

Another possible problem with the feedback manipulations employed is that the specification of constraints of individual problems is a very concrete task. By asking participants to make a list of the constraints, participants were actually being asked to list the specifics of the story that were hindering the solution process. For example, one of the constraints of the aquarium problem is that a high-intensity light placed inside the tank would raise the temperature of the water too high for the fish. While this constraint is analogous to the high intensity rays destroying the healthy tissue and the large force setting off deadly landmines, these constraints are still couched in terms of the specifics of each story. If participants fail to see the similarities between the stories after reading and summarizing them, there is little reason to believe that they will suddenly realize how similar the constraints are after making a list of surface-feature-laden constraints. Therefore, an important question to ask is what kinds of feedback are necessary for a student to learn a class of problems?

Quality of the Convergence Solution

As an outside measure of the quality of the 18 most popular solutions given to the aquarium problem in this experiment, a professor of Biological Sciences was asked to rate each solution on a scale of 1 to 7, with 1 being the best possible solution and 7 being the worst possible solution. Interestingly, the professor only awarded a score of 1 to the option of leaving the fish and plants out of the exhibit altogether. He gave scores of 2 to both the idea of putting the spotlight inside of the tank while cooling the water and to the idea of the designer coming up with a light that does not put out any heat. The remainder of the solutions earned either a score of 5 or of 7. The convergence
solution earned a score of 5. The professor cited two interesting bits of information about the fish in question, one being that the temperature of the tank would have to be kept between 0 and 4 degrees Centigrade, which would explain his preference for the solutions mentioning keeping the heat low. The other fact that he relayed about the deep-sea fish was that while exposure to light will permanently damage their vision, it will not disrupt their feeding habits, as they do not rely on vision to find food.

The fact that the transfer rates in the current experiment do not resemble those reported in the literature should not be due to methodological differences, as all materials and procedures were taken from Holyoak and colleagues (Catrambone & Holyoak, 1989; Gick & Holyoak, 1983). The only exception to this statement is that the radiation problem was used as the target problem in previous work, and the aquarium problem was used as the target in the current study. Taking the expert ratings into account, it could be that the convergence solution was not the best solution to this problem, and therefore depressed the rates of transfer occurred because the convergence solution was correctly rejected by participants. It could be that the convergence solution was a relatively better solution to the radiation problem than it is to the aquarium problem. This difference alone could explain the differences in transfer rates. In support of this argument, one participant stated that many low-intensity lights would be as damaging to fish as a single strong light. Clearly, the student was reminded of the previous stories, but did not feel that the solution was appropriate.

Role of Personal Motivation or Other Personal Dispositions

While there are quite a few possibilities for the current results that can be attributed to task problems, another possible explanation could be in the motivation of the participants. All participants in psychology experiments receive extra course credit for their time. Many students may be participating solely to get the credit, with little regard for the experiment in which they are participating. It might be that those participants

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5 It was mentioned that the radiation problem was not used as the target in the current experiments because of the possibility of interference of participants' knowledge about new cancer treatments. The most recent transfer data being used as a comparison for the current data was published in 1989 by Catrambone and Holyoak, but much of that data was collected earlier than that. It could be that if the radiation problem were used today, transfer rates similar to those observed in the current data would occur.
who are simply “putting in the time,” so to speak, are going to be less likely to expend any significant effort actively participating in the experiment, and may just be “going through the motions.”

These unmotivated participants may be those who are less likely to notice the relevance of the source stories to the target, simply out of a lack of effort. Support for this argument comes from Bransford, Sherwood, Vye, and Rieser, (1986), who noted that students who are better at solving formal analogy problems spend more time encoding the problem than less successful thinkers. Therefore, future experiments using the Gick and Holyoak methodology could include the time participants spent summarizing and comparing the source stories as a measure of motivation.

Ideas for Future Research

Throughout the previous sections, several alternatives to the current methodology were suggested. In this section, these alternatives will be reviewed. First, several ways to circumvent the problem with the constraint analysis manipulation were suggested. These included actually have participants manipulate the aquarium, either using a computer simulation or some actual aquarium set-up. In this way, feedback in the form of constraints can be more closely linked to the participants’ experience of the problems. Related to the feedback presentation issue is the presentation of the source and target problems. If these problems are given to participants in a format that more appropriately displays the spatial nature of the convergence solution, participants may be more likely to see the similarities between them, and they may be better able to see the application of the convergence solution to the aquarium problem. Or, if participants were required to provide a diagram of the source problems and to present their solutions in the form of a diagram, the relationship may be more obvious. Having solvers diagram their solution may be a good alternative to the performance-based task of manipulating the aquarium, in a logistic sense. However, providing feedback to participants who are diagramming their solutions may present the same kinds of problems as the constraint analysis manipulation did in the current experiments. That is, the feedback would more than likely be verbal rather than experiential.

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The discussion of extent of learning the convergence solution yielded several important questions that need to be answered. Briefly these ideas included: (a) the use of a “teacher” to “teach” the class of convergence solutions, (b) the presentation of multiple exemplars, including “near miss” examples (cf. Gick & Patterson, 1992), (c) having participants practice identifying a variety of convergence problems while being given feedback about why their initial choices are or are not examples of these problems, and (d) exploration of different kinds of feedback in order to determine what kind aids in inducing an abstract version of the problem. If any of these ideas work, then one needs to find out how long the effect lasts, and if there are skills that one can teach to enable students to take control over their own transfer processes.

Finally, to deal with the problem of participant motivation, it was suggested that data on the time participants spend processing the source stories could be collected.

**Final comment**

Transfer is a difficult phenomenon to measure, predict, and control. People may not be as bad at transfer as the experimental literature seems to indicate. Or, transfer may only occur reliably within an expert’s domain. Before deciding that the latter is the case, more effort needs to be put forth in designing appropriate, ecologically valid tasks. More attention needs to be given to the way in which the source and target problems are presented, making sure the participants are actually learning the source problems. Also, the importance of feedback in any problem solving situation needs not be ignored, and the way in which this feedback is presented must be considered.
References


LaMotte, L. (April, 1999). Personal communication.


Appendix

Constraint analysis of the Aquarium problem

1. Titanic exhibit needs to have fish and plants that are light-sensitive in order to make it realistic. Therefore, the majority of the tank must be relatively dark.

2. If the tank is too dark, the replica of the ship cannot be seen.

3. Lighting the ship from the inside is too artificial looking.

4. Shining a powerful spotlight onto the ship from inside the tank will raise the water temperature too high for the fish and plants.

5. Shining a powerful spotlight onto the ship from outside of the tank will disrupt the feeding habits of the fish because the bright beam has to travel through the water to get to the tank.
Vita

Ann Elizabeth Speed is a native New Mexican. She completed her undergraduate education at the University of New Mexico in her hometown of Albuquerque. She came to Baton Rouge in August of 1994 to begin graduate work in psychology at Louisiana State University. Her family, including her parents, Jane and Jim Speed still live in Albuquerque. Upon completion of her doctoral degree in psychology after five long years, Ann plans to live and work somewhere in the Southwest United States.
DOCTORAL EXAMINATION AND DISSERTATION REPORT

Candidate: Ann Elizabeth Speed

Major Field: Psychology

Title of Dissertation: The Effects of problem Constraint Analysis on Analogical Transfer

Approved:

[Signatures]

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]

Date of Examination:

May 5, 1999