Analogical Problem Solving: The Differential Impact of Type of Training, Amount of Practice, and Type of Analogy on Spontaneous Transfer

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ANALOGICAL PROBLEM SOLVING: THE DIFFERENTIAL IMPACT OF TYPE OF TRAINING, AMOUNT OF PRACTICE, AND TYPE OF ANALOGY ON SPONTANEOUS TRANSFER

by

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ABSTRACT

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by

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Research on analogical problem solving has delineated several factors that impact one's ability to spontaneously generate a correct solution strategy to a target problem. These factors include, but are not limited to, type of analogy provided to subjects (i.e., partial versus complete), the level of analogical problem-solving expertise, and the absence of or type of analogical problem-solving training (i.e., teacher-generated or learner-generated) provided to learners.

Recently, researchers have begun to focus on providing solvers with multiple practice opportunities and extending these opportunities over a systematically distributed period of time. When combined with analogical problem-solving training, these factors will augment the learner's ability to spontaneously generate a correct solution strategy to both complete and partial target problems.

Using an experimental design, the present study examined the differential effects of type of analogue (partial versus complete), type of training (teacher-generated, learner-generated, or no training), and length of training (condensed versus extended) on novice learners' ability to spontaneously generate correct solution strategies to two target problems.

Findings indicate that, on the complete target problem, regardless of training group membership, no effect over control group participants was found. Partial target problem results indicate a slight advantage for participating in the learner-generated extended training group over no training. Also on the partial target problem, a moderate advantage was found for participating in the learner-generated extended training group over the condensed training.

Limitations of the study, implications for educators, and recommendations for future studies are provided.

(222 pages)

DEDICATION

I would like to dedicate this dissertation to my husband, Chad Michael Petersen, who has been my anchor and greatest fan throughout our graduate experience.

Dune Erin Ives-Petersen

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Dune Erin Ives-Petersen

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GLOSSARY OF TERMS

The following terms and definitions will be helpful to the reader when examining this document. Some replication of definitions may be found in the text where it was deemed necessary to provide the reader with a clear understanding of the study.

Complete problem - a problem that provides the learner each of the following: initial goal state, final goal state, objects, constraints, and correct solution strategy.

Partial problem - a problem that provides the learner at least one but not all of the following: initial goal state, final goal state, objects, constraints, and correct solution strategy.

Isomorphic - two or more problems that are isomorphic to each other have an analogous initial goal state, final goal state, objects, constraints, and correct solution strategies.

Nonisomorphic - two or more problems that are nonisomorphic to each other may be analogous to each other in all but one of the following: initial goal state, final goal state, objects, constraints, and correct solution strategies. The degree of isomorphism between problems is determined by the total number of analogous factors.

PROBLEM STATEMENT

The ability to solve novel problems successfully is not an innate skill that most people possess. In fact, research findings indicate that most solvers are unable to produce correct solution strategies to novel problems without assistance from the researcher (e.g., Gick & Holyoak, 1980). Cognitive and educational psychology researchers have suggested that one effective way to solve problems is to utilize analogies. Analogies assist the learner in thinking of new problems in different ways, and increase the likelihood of developing expertise. When using analogies, people assess novel situations based on previous experiences, apply analogous solutions, and establish more well-developed schemata in the process. In the educational setting, this would be a description of the ideal student. Unfortunately, for most this scenario is not the case; most students do not spontaneously use analogies (e.g., Pierce, Duncan, Gholson, Ray, & Kamhi, 1993). Because students do not spontaneously solve novel problems even when presented with analogies, it is necessary for educators to provide individuals with training on analogical reasoning (Alexander, White, Haensley, & Crimmins-Jeans, 1987).

Training has focused on several factors that influence analogical problem solving. The most effective training programs have focused on the use of hints, use of visual aids, adequate incubation, and a high level of isomorphism between problems (e.g., Alexander, White et al., 1987; Chen, 1995; Holyoak & Koh, 1987; McDaniel & Schlager, 1990; Novick & Holyoak, 1991; Robins & Mayer, 1993).

Although several studies have witnessed positive transfer, much of this research has focused primarily on "teacher-generated" or didactic training (Pierce et al., 1993). This process has more recently been combined with self-monitoring (Osman & Hannafin, 1992) by the subject. In self-monitoring, the subject is trained in employing, monitoring, and evaluating problem-solving strategies. Hence, research on problem-solving strategies is progressing toward mediation of cognitive processes by students; however, even in these new approaches the main methods of problem solving are presented didactically.

Other areas of research have suggested that a more effective training method may be one that focuses on students generating their own training (e.g., Kohn, 1993; McDaniel & Schlager, 1990; Moxley & Covey, 1979). However, there have been extremely few studies that have looked at the impact of such training on problem solving.

In addition to the content of training, cognitive and educational researchers suggest providing multiple training sessions (Bahrick & Phelps, 1987; Sternberg, 1996), and spacing training sessions across time (Madigan, 1969) make the training more effective. Despite the potential these factors appear to have in augmenting training, these variables have not yet been tested in analogical problem-solving studies.

The present study was aimed at filling these gaps. It specifically focused on the effectiveness of actively involving the learner in analogical problem-solving training in comparison to presenting training information through the traditional teacher-generated approach. Additionally, this study investigated the impact of the total number and spacing of training sessions on novice problem solver's ability to correctly solve problems.

LITERATURE REVIEW

Introduction

In everyday life, individuals tend to view problems as extensions of, or similar situations to, previous scenarios they have solved either successfully or unsuccessfully. Consider novice chess players. When individuals first begin playing chess, they have no information on which to base their opening, middle game, and closing moves. However, as they increase the number of games they play, they are able to evaluate moves based on previous similar performances. Upon doing so, they either choose to execute the same move or select another one. Through this process, they add to their repertoire of moves and may eventually become expert chess players. In essence, this is analogical problem solving, the application of a solution or outcome from a similar situation to the present situation (Chen, 1995; Gentner & Holyoak, 1997; Keane, 1988; Kolodner, 1997; Reeves & Weisberg, 1993; Seel & Hoops, 1993).

Unfortunately, as Ross (1984) noted, "for people unfamiliar with a domain, even if a rule [or move, as in chess] is remembered perfectly, it may not be applied successfully" (p. 374). It is out of this deficiency that cognitive and educational psychology researchers have incorporated the use of analogies in problem-solving studies (Spencer & Weisberg, 1986). Analogies benefit learners by helping them to think about problems differently (Catrambone & Holyoak, 1989) and to combine new and previously learned information into more well-developed schemata (Ross, 1984; Zook, 1991). Using these schemata, problem solvers are more apt to make inferences and increase their understanding about current events or problems (Solomon, 1991; Stein, Way, Benningfield, & Hedgecough, 1986).

In its most basic form, analogical problem solving consists of deriving from memory (retrieval) a solution from a previously encountered problem (the base problem or analogy) and using it (mapping) to solve a novel problem (termed the target problem; Antonietti, 1991; Clement, 1988; Gick & Holyoak, 1980, 1983; Klauer, 1989; Novick & Holyoak, 1991; Okagaki & Koslowski, 1987; Reeves & Weisberg, 1993; Seel & Hoops, 1993; Spencer & Weisberg, 1986; Wickelgren, 1974; Zook, 1991). More specifically, this analysis involves assessing both base and target problems for their surface and structural similarities, including their initial and final goal states, and using their similarities and differences in determining the most appropriate solution strategy to satisfy the current problem's goals (e.g., Okagaki & Koslowski, 1987).

Similarly, analogical transfer refers to the retrieval and mapping of an analogous solution (Klauer, 1989; Novick & Holyoak, 1991; Reeves & Weisberg, 1993), but goes one step further by assessing how "successful" these processes are. Three types of transfer have been identified in the existing literature: (a) positive transfer, (b) negative transfer, and (c) spontaneous transfer (Clement, 1988; Gick & Holyoak, 1980; Gick & McGarry, 1992; Novick, 1988; Pierce & Gholson, 1994; Ross, 1987). The similarity of base and target problems and the application of base solutions determine what type of transfer has occurred (Novick, 1987). A solution derived from an analogous base problem and used correctly would yield positive transfer. More specifically, stating that positive transfer has occurred indicates that the target problem was correctly solved using an analogous base problem's solution. Conversely, if a solution from a nonanalogous, or irrelevant, base problem is applied to the target problem, negative transfer may result. Spontaneous transfer is a subset of positive transfer and refers to the point at which a subject derives the correct solution. If the correct solution is derived before a hint to use an analogous problem is given, spontaneous transfer has occurred. However, if the correct solution is derived after a hint is given, positive transfer is the result. The majority of studies have focused their efforts on determining whether positive or spontaneous transfer has occurred. The present study will not incorporate the use of hints or other assistance in its design, and as such focuses on the prevalence of spontaneous transfer only.

Processes Involved in Analogical Transfer

Although the semantics used in describing analogical problem solving vary from study to study, five processes appear to cut across studies: (a) goal identification, (b) representation of base and target propositions/relations, (c) schema induction and adaptation (retrieval), (d) mapping (application), and (e) learning (Alexander, Wilson, et al., 1987; Chen, 1995; Clement, 1988; Funkhouser, 1990; Gentner, 1989; Gholson, Eymard, Morgan, & Kamhi, 1987; Gick & Holyoak, 1980; Hirschman, 1981; Holyoak & Thagard, 1989; Keane, 1985; Mayer, 1985; Needham & Begg, 1991; Novick, 1988; Novick & Holyoak, 1991; Pierce at al., 1993; Pierce & Gholson, 1994; Reeves &

Weisberg, 1993; Ross, 1984; Vosniadou, 1989; Zook, 1991). Each of these processes will be briefly defined below.

Goal Identification

Goal identification refers to the learner's ability to identify the primary objectives of the problem. Keane (1985) suggested that problem solvers must attend to "(a) the role the object concept plays in the domain (agent, object, instrument, etc.), (b) any attributional overlap between parallel objects in both domains, and (c) 'functionally relevant attribute' information" (p. 450). Understanding these aspects of both the base and target problems may, in fact, be the most important first step in one's ability to generate a correct solution (Gick & Holyoak, 1980). Those studies that have employed analogies with similar goal states have increased the learner's identification of correct goals and facilitation of positive transfer (Okagaki & Koslowski, 1987).

Also important is the discrepancy between the goals of the problem solver and the goals of the problem (Gentner, 1989; Holyoak & Thagard, 1997). Ideally, the learner's interpretation of the problem's goals and the actual problem's goals will be isomorphic in nature. If, however, the solver evaluates the problem with an entirely different focus than is intended, the solver may access an inappropriate schema, thereby reducing the probability that positive transfer would be obtained.

Problem Representation

After the initial and final goal states of the problem have been identified, it is important for the problem solver to be able to attend to the appropriate information in the base and target problems (Black & Rollins, 1982; Bransford & Stein, 1984; Reeves & Weisberg, 1993; Ross, 1987). In essence, this means that "learners must be able to disregard the superficially dissimilar characteristics of two or more analogous domains and attend to the common relational structure" (Zook, 1991, p. 42). Problem representation is necessary to make an accurate and efficient comparison of the analogies and retrieve appropriate analogy solutions (Mayer, 1985; Novick & Holyoak, 1991; Ross, 1984). Failure to do so has been found to lead to a decrease in positive transfer (Keane, 1985; Silver & Marshall, 1990).

Schema Induction

Schema induction, also referred to as retrieval and solution generation, has been noted to be the most arduous of all the processes, yet it has been posited that the development and retrieval of relevant schemata will lead to an increase in problem-solving expertise (Novick & Holyoak, 1991). Schema induction entails making connections between previously learned information and the goals of the present problem and retrieving this previously learned information (Clement, 1988; Funkhouser, 1990; Orlich, 1992). It has also been postulated that subjects who produce and utilize well-developed schema, through a comparison of base and target structural relations and are able to adapt their solution to fit the target problem, tend to experience more positive transfer (Gick, 1981; Keane, 1985; Klauer, 1989; Novick & Holyoak, 1991; Ross, 1984; Seel & Hoops, 1993). Moreover, in a study on the effects of using instructional analogies to aid the process of solution production, Zook (1991) found that the most useful analogies are those that either "1) activate pre-existing schemata or 2) facilitate the induction of new schemata" (p. 48).

Mapping

Once the solver has retrieved or constructed an appropriate solution, she/he must apply it to the target problem (Heydenbluth & Hesse, 1996; Mayer, 1992; Novick & Holyoak, 1991; Pierce & Gholson, 1994; Vosniadou, 1989) through a mapping process. The key to the mapping process is that it provides the problem solver information on how to solve the target problem. If the retrieved solution is mapped onto the target problem and in the process is deemed to be irrelevant, the problem solver must then retrieve a more appropriate solution strategy and repeat the mapping process until a correct solution for the target problem is generated. This process can be facilitated by eliminating any irrelevant information specific to the target or base problems (Black & Rollins, 1982), which may lead to clear identification of the structural similarities of both problems (Ross, 1987). Conversely, hindrances may include "a) surface and structural dissimilarity between analogs, b) impoverished representation of base domain knowledge, c) overextension of the base domain, d) learner misperception of the analogy's instructional purpose, or e) inexperience in mapping procedures" (Zook, 1991, p. 61). Mapping failures may also stem from the learner's inability to generate a solution that meets the criteria of the target problem's goals (Keane, 1985). However, successful mapping may allow the learner to generate the correct solution strategy to the target problem. In other words, analogical transfer would result.

Learning

The final stage in analogical problem solving occurs when the solver adds the new solution strategy to his/her existing schemata (Bransford & Stein, 1984; Hirschman, 1981; Holyoak & Thagard, 1989; Novick & Holyoak, 1991). This process does not occur by itself alone. Rather, it is a product of the first four stages in this "evolutionary" process of analogical problem solving in which an association between similar base and target problems is made. Once this association is made, the solver retrieves information from the base problem, maps it onto the target problem, generates a solution for the target problem, and adds the new solution to his/her existing long-term memory base. Thus, learning has occurred, which allows the solver to progress toward "expert" status in problem solving (Novick & Holyoak, 1991).

Facilitation of Positive Transfer

Researchers have identified several factors that influence problem solving. For clarity, these factors are divided into four categories: (a) type of analogy, (b) problem solver characteristics, (c) analogical problem-solving training, and (d) factors affecting training. Not all of the factors that impact analogical transfer are discussed in this dissertation. Rather, only those factors that have been shown or suggested to have the greatest impact on spontaneous transfer have been included in this study. See Holyoak

(1985) or Zook (1991) for a more comprehensive look at factors that facilitate positive transfer.

Type of Analogy

Researchers have employed several manipulations of analogy formats in problem-solving studies. The most prevalent include, but are not limited to, problems that vary on surface or structural similarities, complete versus partial analogies, and the use of multiple analogies.

Structural Versus Surface Similarities

Perhaps the factor that accounts for the greatest impact on positive transfer is the similarity between surface and structural features shared by the base and target problem. Surface features of a problem may include its objects (e.g., houses, boats), settings (e.g., time of year, place), or other elements that may be unnecessary to the generation of a correct solution strategy (Mayer, 1992; Pierce & Gholson, 1994; Vosniadou, 1989). In contrast, structural features are the propositional statements of a problem that may influence goal attainment (e.g., initial and final goal states; Heydenbluth & Hesse, 1996; Holyoak, 1985; Mayer, 1992; Novick, 1988). As Holyoak and Koh (1987) stated:

> Spontaneous analogical transfer is more likely to occur when the target problem shares multiple features with the source analogy. Both salient surface features, which do not impede achievement of the critical solution, and deeper structural differences, which involve the nature of the solution constraints, have an impact on transfer. (p. 338)

Essentially, the amount of structural and surface similarity that exists between the target and analogical problems will increase or decrease the probability of obtaining positive transfer (e.g., Antonietti, 1991; Chen, 1995; Gick, 1981; Gick & Paterson, 1992; Okagaki & Koslowski, 1987; Orlich, 1992; Solomon, 1984).

Successful transfer is further influenced by whether a problem solver focuses primarily on surface features, structural features, or a combination of both. When a problem solver focuses only on the surface similarities between problems, she/he often will experience difficulty in accessing the appropriate schema and producing the target problem's solution (Holyoak, 1985; Holyoak & Koh, 1987; Novick, 1988; Ross, 1984; Zook, 1991). This is due in part to the absence of relevant and vital information that is uncharacteristic of surface features (Novick, 1988), as well as the tendency of the solver to become fixated on the irrelevant surface features, thereby being unable to identify and use the propositional relations between the base and target problems that are essential for correct solution generation (Zook, 1991). Related to this is the finding that identification of structural similarities yields a high rate of positive transfer (Zook, 1991), as does attention given to both surface and structural similarities (Orlich, 1992).

Complete Versus Partial Analogies

The base analogy can also vary with regard to what information it provides the solver, in comparison to what information is required to solve the target problem. A problem may include the initial and final goal states of the problem, objects, constraints, and the analogy's solution. A complete analogy will provide all of this information. Conversely, a partial analogy provides the solver with one of the aforementioned parts, but not all (Antonietti, 1991). For example, solvers may be presented with an analogy's solution and not know exactly how that solution was obtained, or they may receive the initial and final goal states and not know how to solve the analogy. In a study designed to determine the facilitating effects of using partial versus complete analogies, Antonietti (1991) found that subjects who received a complete analogy yielded a higher rate of positive transfer than did subjects receiving only partial analogies, $P_{partial} = .12$, $P_{complete} = .50$, $p < .05$. Research findings are supported by reporting the value of the statistic (e.g., U its degrees of freedom and p value unless this information is not provided in the original document.)

Multiple Analogies

The use of multiple analogies in problem-solving studies has facilitated greater positive transfer (Antonietti, 1991; Catrambone & Holyoak, 1989; Gick & Holyoak, 1980, 1983) than the use of one analogy or no analogy. Despite this finding, positive transfer will only be found if these analogies are similar in structure to the target problem (Gick & Holyoak, 1980), thereby increasing the learner's ability to delineate relevant features in the problems (Gholson et al., 1987). To better understand this, consider a study conducted by Catrambone and Holyoak (1989) that presented two groups with either two isomorphic or one isomorphic and one nonisomorphic analogy. (For the definition of isomorphic and nonisomorphic, please refer to the Glossary of Terms section at the beginning of this document.) Subjects in the two-isomorphic group produced the correct solution more often than did those in the second group, LR ($df = 1$) = 7.16, $p < .01$. Thus, presenting subjects with multiple isomorphic analogies can aid solvers in the transfer process because it affords subjects more practice with analogical problem-solving processes, and multiple analogies may provide subjects with additional information that, if retrieved, will assist them in solving the target problem.

Problem Solver Characteristics

Not all solvers bring with them the same amount of domain or general knowledge to a learning situation. The amount and kind of knowledge they possess, as well as their ability to adequately retrieve and map this information, can greatly influence the probability of obtaining positive transfer. In the literature, problem solver characteristics have most often been discussed in terms of expert and novice problem solvers (e.g., Novick, 1988). As such, this study will utilize the same distinction.

Researchers posit that novice solvers are less likely than expert solvers to successfully solve novel problems because of their tendency to focus more time and effort on irrelevant features (Chi & Van Lehn, 1991; Marr & Sternberg, 1986). Novice solvers also focus more on the surface features of the base and target problems (Brown, 1989; Chi, Feltovich, & Glaser, 1981; Hirschman, 1981; Kolodner, 1997; Meijer & Riemersma, 1986; Novick & Holyoak, 1991; Pirolli & Bielaczyc, 1989), thereby decreasing the likelihood of successful transfer.

In contrast, experts focus more time on relevant and both structural and surface similarities (Hirschman, 1981; Ross, 1984; Silver, 1979) and are better able to derive important information needed to solve the target problem (Chi et al., 1981; Chi & Van Lehn, 1991; Pirolli & Bielaczyc, 1989; Seel & Hoops, 1993). Expert/gifted solvers have also been found to use more than one method of solution generation and they tend to use more analogies than do novice/average solvers in this process, $U(N = 30) = 2.15$, $p < .03$ (Jausovec, 1993, experiment 1). Experts can better assess their level of understanding of an example (Chi & Van Lehn, 1991). Also related to this is the amount of knowledge a problem solver has in a particular domain. Studies, most of which focus on the domains of physics and mathematics, have found that a learner's prior knowledge may facilitate positive transfer (Clement, 1988; Novick, 1988; Solomon, 1984, 1991; Stein et al., 1986). To illustrate, Novick (1988) explored differences among expert and novice problem solvers on an analogical problem-solving test requiring mathematical knowledge. (Level of expertise was determined by scores on the match section of the SAT. Subjects scoring between 500 and 650 were classified as novice and subjects scoring between 690 and 770 were designated experts. Thus, experts brought with them prior mathematical knowledge.) It was found that experts experience more positive transfer than do high novices and low novices, 54%, 29%, and 22%, respectively, $F(1,65) = 6.46$, $p < .02$. Thus, it appears that experts bring with them prior experience in problem-solving situations and the ability to reason inductively. Given these findings, novice learners may benefit more from analogical problem-solving training than expert learners. This training would provide novices with the skills and knowledge needed to generate correct solution strategies to target problems.

Analogical Problem-Solving Training

Despite the knowledge regarding what will facilitate positive transfer, alarming evidence exists to suggest that the prevalence of a low rate of transfer is not uncommon in cognitive and educational psychology studies, even in research in a wide assortment of domains (Brown, 1989; Pierce et al., 1993; a low rate of transfer has been described in the literature as less than 10% of the sample being able to spontaneously generate a correct solution strategy to the target problem [e.g., Gick & Holyoak, 1980]). In an attempt to augment a solver's level of analogical problem-solving ability, researchers have employed the use of problem-solving training in their studies (e.g., Gagné, Yekovich, & Yekovich, 1993; McDaniel & Schlager, 1990). Many researchers contend that without explicit instruction, problem solvers are unable to accurately represent problems (Keane, 1985; Reed, Dempster, & Ettinger, 1985), retrieve the appropriate schemata (Klauer, 1989), and may not know exactly how to map or adapt this retrieved information (Gick & Holyoak, 1987; Royer, 1979; Schoenfeld, 1979). As Alexander, White, et al. (1987) suggested, "Maintenance and transfer will more readily occur when we systematically teach for them" (p. 388).

By training learners in the analogical problem-solving process, they will be better able to think of problems in new ways (Catrambone & Holyoak, 1989; Chi &

Van Lehn, 1991; Mayer, 1987), identify similarities between base and target problems (Alexander, White, et al., 1987; Klauer, 1989), and consider several possible solutions to target problems (Bloom & Broder, 1950; Mayer, 1987; Stein et al., 1986). Perhaps more importantly, problem solvers may become critical thinkers when selecting and applying potential solutions (Bransford & Stein, 1984; Osman & Hannafin, 1992), and, as a result, their academic achievement (Loewenthal & Pons, 1987) and learning (Ross, 1989) may increase.

An effective training program should engage the learner on each of the aforementioned elements that have been found to impact analogical transfer (e.g., practice with multiple analogies, structural and surface similarities of base and target problems, use of partial and complete analogies), as well on each of the stages of analogical problem solving (e.g., goal identification, mapping). Focusing and engaging the learner on these elements and stages will aid him/her in future accessing of pertinent information, and, ultimately, spontaneous transfer (Kelly, Scott, Prue, & Rychtarik, 1985).

Types of Analogical Problem-Solving Training

Analogical problem-solving training can be broken down into two categories: (a) teacher-generated training and (b) learner-generated training. Teacher-generated training refers to training developed by the teacher or researcher and presented to the problem solver in a didactic teaching style. Conversely, learner-generated training is one that is developed by the solver and guided by the teacher through a guided discovery learning process. Subtypes of training within each of these categories, as well as research findings on these methods, will be discussed in the following sections.

Teacher-generated training. The most prevalent type of analogical problem-solving training is teacher- or researcher-generated. This training primarily involves direct instruction on problem-solving strategies (Alexander, Wilson, et al., 1987; Black & Rollins, 1982; Brooks & Dansereau, 1983; Brown, Campione, & Barclay, 1979; Cramond, Martin, & Shaw, 1990; de Volder & de Grave, 1989; Fong, Krantz, & Nisbett, 1986; Funkhouser, 1990; Gabel & Sherwood, 1983; Mayer, 1985; Schoenfeld, 1979), problem types (Robins & Mayer, 1993; Seel & Hoops, 1993), base and target problem representations (Catrambone & Holyoak, 1989; Cramond et al., 1990; Mayer, 1985), problem-solving processes (Bloom & Broder, 1950; Funkhouser, 1990), and the use of multiple practice problems (Cramond et al., 1990; Stein et al., 1986) and similar base and target problems (Gholson et al., 1987). In the typical teacher-generated classroom setting, the teacher would lecture on a subject with little or no interaction from students other than during a clarification period.

This type of training has also incorporated the use of hints or suggestions to evaluate the similarities of base and target problems, thereby focusing the learner on relevant features (Orlich, 1992; Stein et al., 1986). Most analogical transfer research has found that without a suggestion to utilize previously learned information, problem solvers are unable to produce the target solution (Catrambone & Holyoak, 1989; Gick, 1981; Gick & Holyoak, 1980, 1983, 1987; Hesse & Klecha, 1990; Reeves & Weisberg, 1993; Solomon, 1984). To illustrate, Gick and Holyoak (1980) found that

92% of the subjects who were given a hint to use the general analogy were able to produce the convergence solution to the target problem, while only 20% of the subjects who were not given a hint were able to do so. However, it is important to note that this type of training results in positive transfer, through the use of hint, rather than the more desirable spontaneous transfer.

As purported by Schoenfeld (1979), one way to increase spontaneous transfer in analogical problem solving is to train students in general problem-solving skills rather than specific strategies, because of the need for problem solvers to be able to generalize strategies, or schemata, from one novel problem to the next. This point is echoed by McDaniel and Schlager (1990), who stated that it is important that "the strategy is well learned and...applicable for the transfer problem" (p. 141). This training would introduce the solver to the strategy and provide direct instruction on when and when not to use it.

To illustrate, Alexander, Wilson, et al. (1987), trained fourth graders on how to complete analogical reasoning tasks through instruction on analogical problem-solving processes as well as practice with multiple problems. Results indicate that trained subjects exhibited more spontaneous transfer than did nontrained subjects ($F = 11.98$, $df = 1,33$, $p < .002$) on both immediate ($F = 17.82$, $df = 1, 33$, $p < .001$) and delayed posttests ($F = 11.54$, $df = 1, 33$, $p < .002$). Thus, findings from these studies suggest that training such as those described here facilitate a higher level of performance over an extended period of time.

Learner-generated training. Several researchers have acknowledged the potential benefits of utilizing students in their own learning process (e.g., Ives, 1996; McDaniel & Schlager, 1990; Moxley & Covey, 1979), especially because problem solving is viewed as a creative endeavor that requires students to be able to discover on their own answers to problems (Laing, 1985). McDaniel and Schlager (1990) promoted the incorporation of discovery learning in analogical problem solving as it provides students the opportunity to learn new procedures that will aid them in generating correct solution strategies to novel problems. Moreover, Seel and Hoops (1993) argued for a guided discovery teaching method when teaching for transfer that would provide students the opportunity to generate their own analogies and problem-solving processes. At the same time, teachers or researchers would provide students with assistance in increasing the appropriateness of these analogies and processes (Woods, 1993), which may lead to a higher prevalence of spontaneous transfer. In summary, in a learner-generated or guided discovery environment the instructor would provide a basic problem-solving foundation on which students would discover, with minimal assistance from the instructor, the problem-solving processes to use to spontaneously generate correct solution strategies to target problems.

To answer these calls for student participation, some researchers have taught self-monitoring as a tool to use when problem solving (Brown et al., 1979; Cramond et al., 1990; Osman & Hannafin, 1992; Pierce et al., 1993), but self-monitoring does not target student generation of appropriate steps to take when solving a problem. (Self-monitoring has also been referred to as self-control, but for consistency both will be labeled self-monitoring in this study.) Rather than incorporating active student participation in generating the problem-solving process, self-monitoring consists of teacher-generated instruction on the employment and monitoring of problem-solving strategies with students using and monitoring the prescribed process. There is no student discovery of best practices in self-monitoring. Thus, self-monitoring is not much different from the more traditional teacher-generated training in augmenting subjects' problem-solving ability.

In a study investigating the effects of either instructing students on the move sequence and strategy needed to solve a new problem (ND) or having students discover the move sequence (MD) or both move sequence and strategy (SMD), McDaniel and Schlager (1990) found that on a near-transfer task, SMD subjects produced faster solutions ($F = 7.50$, $df = 1, 228$, $p < .05$, $MSE = .21$) and fewer total moves ($F = 3.64$, $df = 1, 228$, $p < .05$, $MSE = .20$) than did the MD subjects.

Comparison of Teacher-Generated and Learner-Generated Training

Perhaps the most direct research into the effects of learner-generated training was conducted by Ives (1996). In this study, novice problem solvers participated in either a teacher-generated training in which they were didactically presented with the stages of analogical problem-solving, or they participated in a learner-generated training in which participants developed the analogical problem-solving steps on their own and were guided by the teacher to use the steps in the appropriate order. Training sessions provided learners practice with multiple base and target problems and practice with using partial and complete analogies. The two training groups were compared against each other and against a control group in which participants did not receive specific training, but did receive exposure to the same problems used in the learner- and teacher-generated groups. Participant's performance was measured by the correctness of their solutions to a partial and a complete target problem.

When looking at novice solvers' solutions to the complete target problem, no statistically significant differences were found among the training groups, $\chi^2(2, N = 28) = .25$, $p < .88$. However, when considering performance on the partial target problem, a trend for solvers to benefit from training was found with solvers in the learner-generated group provided more correct solution strategies (20.0%) than did those in the teacher-generated group (12.5%), and both training groups outperformed the control group (0.0%). This trend is further explicated through effect size analyses. When comparing the teacher-generated and learner-generated groups, a small effect size of .19, $\chi^2(2, N = 18) = .18$, $p < .67$, was found; however, comparisons between teacher-generated and control groups, $\chi^2(2, N = 18) = 1.69$, $p < .19$; $d = .61$, and learner-generated and control groups, $\chi^2(2, N = 20) = 2.99$, $p < .08$; $d = .80$, revealed medium to large effect sizes. Thus, it appears that novice solvers benefited more from receiving teacher-generated and learner-generated training than solvers receiving no problem-solving training.

In summary, no statistically significant differences were found in overall comparisons between the three training groups on the partial, $\chi^2(2, N = 28) = 3.03$, $p < .21$, or complete, $\chi^2(2, N = 28) = .25$, $p < .88$, target problems. The lack of statistical significance may be indicative of sample size or chance findings or as result of training format. As the training and learning literature would suggest, key factors such as additional practice and adequate spacing between practice sessions may greatly impact training.

Analysis of this study's training format reveals that learners participated in a short training program consisting of only one practice session that may not have been long enough for student learning and retention to occur. In addition, it was anecdotally noted by the author that students may not have been motivated to participate in and learn information from the training sessions, again contributing to the lack of statistically significant differences. However, given the trends found between training and control groups, future studies should focus on the impact length of training and amount of practice have on analogical problem-solving performance.

Factors Affecting Training

Despite having effective content in effective training programs, cognitive theory suggests that for successful learning to occur, learners should participate in multiple training sessions and these sessions should be spaced across time. Each of these factors has been well documented in the literature and, as such, the factors are only briefly discussed in this study. For further examination, see Moss (1995) for practice effects and Dempster and Farris (1990) for spacing effects.

Practice Effect

The theory of practice effects suggests that greater gains in future performance will occur as a direct result of additional practice with the learning material (Bahrick & Phelps, 1987; Sternberg, 1996). This theory is similar to the total time hypothesis that states that one's overall learning performance will increase as a result of the amount of time one spends rehearsing the material to be learned (Sternberg, 1996). A direct implication of these findings suggests that problem-solving training that includes numerous problem-solving activities should result in higher levels of spontaneous transfer. Despite the implications practice effects has for student performance in future problem-solving exercises, this theory has not been tested in the realm of analogical problem-solving performance.

Spacing Effect

The spacing effect theory states that recall of information to be learned will increase if information is presented over a systematically distributed period of time and is interspersed among additional activities, thereby increasing the amount of time for processing and elaborating between sessions (Anderson, 1990; Dempster & Farris, 1990; Glenburg, 1979; Moss, 1995; Sternberg, 1996). Thus, in a classroom, student learning will increase more if information to be learned is spread out over a given amount of time rather than if information is presented in one session. Again, a direct implication of this research indicates that not only should problem-solving training provide numerous problem-solving activities, but it should also distribute these activities across several training sessions to increase levels of spontaneous transfer. However, there have been no studies that have tested spacing effects on student analogical problem-solving performance.

Summary

Current problem-solving literature suggests that improving a learner's analogical problem-solving ability may lead to several benefits. One of the most effective ways to facilitate such improvement is to provide learners with problem-solving training. However, it is unknown whether teacher-generated training is more effective than learner-generated training or to what extent factors such as practice time and spacing effects influence the effectiveness of this training. Given this, research is needed that examines the differential impacts of type of training, amount of practice received during training, and amount of lag time between presentation of training elements on a learner's ability to spontaneously generate correct solution strategies to complete and partial target problems.

THE STUDY

Purpose of the Study

Widespread study on the impact of using analogies in problem solving has afforded researchers and educators alike much information regarding how best to help students reach "expert" problem-solving status. At present, researchers have begun to examine the effectiveness of training subjects in problem-solving skills. In addition, there is evidence in areas such as cognitive and educational psychology that when the student is involved in developing that training, learning may become a more meaningful activity that results in increases in spontaneous transfer. Previous research also suggests that providing students with practice and an adequate amount of lag time between training sessions may augment their levels of learning. However, these factors have not yet been applied to analogical problem solving.

The purpose of this study was to investigate the relative effectiveness of teacher-generated and learner-generated training on spontaneous transfer. Based on findings from previous studies, several factors have been identified as likely to influence spontaneous transfer. Each of these factors were included in this study to determine their relative effects on spontaneous transfer. The present study tested four hypotheses:

1a. Providing analogical problem solving training results in higher levels of performance on the complete target problem than does no training.

1b. Students who receive learner-generated extended training will yield the highest levels of spontaneous transfer on the complete target problem than will learner-generated condensed, teacher-generated extended and condensed, and control students.

2a. Providing analogical problem solving training results in higher levels of performance on the partial target problem than does no training.

2b. Students who receive learner-generated extended training will yield higher levels of spontaneous transfer on a partial target problem than will learner-generated condensed, teacher-generated extended and condensed, and control students.

Method

Design

This study used an experimental design. The dependent variable used to measure problem-solving performance was accuracy of response to two problem-solving exercises. The independent variables included training group (TG, LG, or control), length of training (condensed or extended), and type of analogy (partial or complete).

Subjects

Subjects were 110 novice problem solvers from two undergraduate classes (Psychology 101 and 110) at Utah State University. (The identification procedure and rationale used in selecting only novice problem solvers is provided in the materials section that follows.) The average age of participants was 21 (range = 18 to 39) and their average GPA was 2.80 (range = 1.40 to 3.3). Seventy-five percent of the sample was female, and almost half (46%) were freshmen (sophomores = 38%, juniors = 14%, seniors = 2%). Psychology 101 and 110 were selected primarily to provide a broad spectrum of college students representing a variety of majors and to use students similar to those used in previous research (e.g., Ives, 1996). Participation was sought on a volunteer basis with students receiving extra credit for participating in the study. Students also became eligible to win one of four $50.00 cash prizes for completing the study, and one $200.00 cash prize based on performance during training and testing (see Appendices A and B).

Materials

Problem-Solving Ability Test

To assess the problem-solving ability of subjects, a three-problem test (see Appendix C) was administered to subjects at the time of recruitment. The problems selected to be used on this test have been used in numerous studies with subjects similar to the ones used in the present study (e.g., Antonietti, 1991; Gick & Holyoak, 1983; Ives, 1996; Simon & Hayes, 1976). These problems were previously pretested on 15 Psychology 101 undergraduate students at Utah State University who were presumed to be similar to those who were used in this study (Ives, 1996). Pretesting revealed no ceiling or floor effects and that subjects understood the problems. To test the consistency of classifying students as expert or novice learners, each problem was replicated using the same structural features as the corresponding original problem but with different surface features, thereby creating two parallel tests. The two tests were administered, immediately after each other, using the same administration protocol with each of 20 Psychology 366 undergraduate students at Utah State University, presumed to be similar to those who were used in the present study. Subjects were required to solve all six problems, and solutions were scored as either correct or incorrect. Subjects who solved two or three problems correctly were labeled as expert problem solvers, and those who solved zero or one problem correctly were labeled as novice problem solvers. Using Hambleton and Novick's (1973) measure of decision-making consistency, *P*, the estimated probability of a consistent decision was .90, which indicates that 90% of subjects were classified as novices or experts consistently across the two tests. The same administration and scoring procedures were used with the present study's participants. Findings from previous studies (e.g., Ives, 1996) have found that expert solvers do not benefit from problem-solving training. Given this, only novice problem solvers were used in this study.

Training Protocols

In order to train subjects for the present study objectives, three groups of training protocols (i.e., teacher-generated, learner-generated, and control) were developed from existing studies on problem-solving factors such as training in strategies and types of problems, use of partial versus complete problems, and use of multiple analogies.

Teacher-generated training. The first group of training protocols included two protocols, one used with the group that received training during one 2-hour session (condensed training) and one used with the group that received training over a 3-day period (extended training). These protocols provided subjects with a highly structured discussion of problem-solving strategies and methods, and did not allow for any participant interaction unless participants needed clarification.

During the condensed training session, participants received direct instruction on problem-solving strategies, on making comparisons between base and target problems, on the sequence of steps that should be taken when solving a problem using an analogy, and on a recap of the steps that were used to derive the correct solution strategy to practice target problems. Upon completion of the practice problems, participants received feedback on their progress in applying analogical solution strategies. During the extended training session, participants received the same problem-solving information as presented in the condensed training session, but the extended training session provided additional practice time to use problem-solving skills. The detailed procedures used with the TG groups can be found in Appendix E.

Learner-generated training. The second group of training protocols included two protocols, one for use with the group that received training during one 2-hour session (condensed training) and one used with the group that received training over a 3-day period (extended training). These protocols also provided subjects with a structured discussion of problem-solving strategies, but the discussion of problem-solving methods was highly dependent on active student interaction where students developed their own problem-solving criteria and steps. The sequence of presentation of material during the three sessions was the same as the TG sequence, and the detailed procedures used with the LG groups can be found in Appendix F. As with the TG training, upon completion of the practice problems, participants received feedback on their progress in applying analogous solutions. However, because the LG training was designed to actively involve the learner, the feedback provided was more tailored to specific questions the learner had during the solution process.

Control group. The third group of training protocols was designed to provide the same level of exposure to problems as TG and LG groups during a single one-hour session without providing any direct training on the problem-solving process. Unlike the TG and LG sessions, control students did not receive any feedback on their ability to apply the problem-solving process. Students were simply shown the correct solution strategy. The detailed procedures used with the control group can be found in Appendix D.

All protocols were pretested with separate samples of 20 undergraduate psychology students who were presumed to be similar to subjects used in this study. At the conclusion of each training session, subjects were asked to identify what the objectives of the training were and to identify any areas where presentation of material could be improved. (Participants correctly identified the training objectives, which suggested that the protocols were effective in helping them to understand the material presented to them and that information was delivered in an easily comprehensible manner.) The results of the pilot testing suggested that no revisions to the protocols were necessary.

Training Problems

The final materials used in this study were the training and testing problems, found in Appendices G and H, respectively. While three of the problems were developed by the present author, most have been used in numerous studies with subjects similar to those in this study (e.g., Duncker, 1945; Gholson et al., 1987; Gick & Holyoak, 1980, 1983; Reed, Ernst, & Banerji, 1974; Wickelgren, 1974). Permission, either verbal or written, was obtained for the use of each problem. These problems include the Tower of Hanoi three- and five-disk problems (see Appendix K), the poker problem, the three little pigs problem, the hobbits and orcs problem, the apples and oranges problem, the quiz game problem, the casino problem, the book burners and book lovers problem, the ants problem, the birthday party problem, the pendulum problem, the fireman problem, the inaugural gala problem, the identical twins problem, the jungle problem, the street vendor problem, the trump suit problem, the parade problem, the wine merchants problem, the traveler problem, the poisoned cups problem, the missionaries and cannibals problem, the general problem, the Renshaw problem, and the marching band problem.

All of the aforementioned problems are either complete or partial problems. The complete problems included the initial goal states, final goal states, objects, constraints, and a solution strategy. Conversely, in this study, a partial problem included everything but the solution strategy. Additionally, each problem was either isomorphic or nonisomorphic to other problems. Isomorphic problems are completely analogous to each other, whereas in nonisomorphic problems there is some element of the two problems that is incongruous. For example, the missionaries and cannibals problem was isomorphic to the book burners and book lovers problem in that they had similar initial and final goal states (i.e., in both problems one must find the best route to get six people across a river), the same objects (one boat and six people--three "good" and three "bad"), the same constraints (the boat can only hold two people, one person must be in the boat for each crossing, and the "bad people" cannot outnumber the "good people" at any time), and shared the same solution strategy (see Appendix I.) In contrast, the cannibal problem was considered to be nonisomorphic to the wine merchants problem. In these two problems, the initial and final goal states were different (transport driver, wine, horse, and cart across a raging river), there were a differing number of object types (four instead of two) and different constraints (the driver must battle a raging river and accommodate his tired horse), and they had somewhat different solution strategies (see Appendix I).

Testing Problems

During the final testing session, subjects were provided with two problems: the radiation problem and the jealous husbands problem (see Appendix J). As seen below in Figure 1, the radiation problem was isomorphic to the general, parade, and fireman analogies, and nonisomorphic to the jungle, wine merchants, and poisoned cups analogies provided during the training group sessions. As discussed in the procedure section, these six analogies were presented as partial analogies, and inclusion of the radiation problem in the testing session was designed to test the facilitating effects of

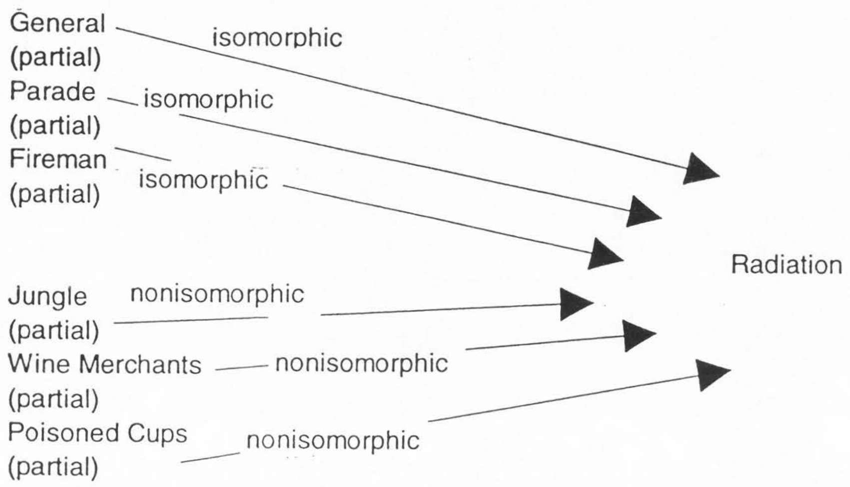

Figure 1. Relationships between analogies presented during training group sessions and the radiation testing problem.

training with multiple partial analogies on the spontaneous generation of the solution to a target problem.

As found in Figure 2, the jealous husbands problem was completely isomorphic to the missionaries and cannibals, book burners and book lovers, and hobbits and orcs analogies, and nonisomorphic to the Renshaw, marching band, casino, three little pigs, and traveler analogies presented in the group sessions. As discussed in the procedure section, these analogies were completely solved during the training sessions. Thus, the jealous husbands problem was presented during the testing session to test the facilitating effects of training with multiple complete analogies on the spontaneous

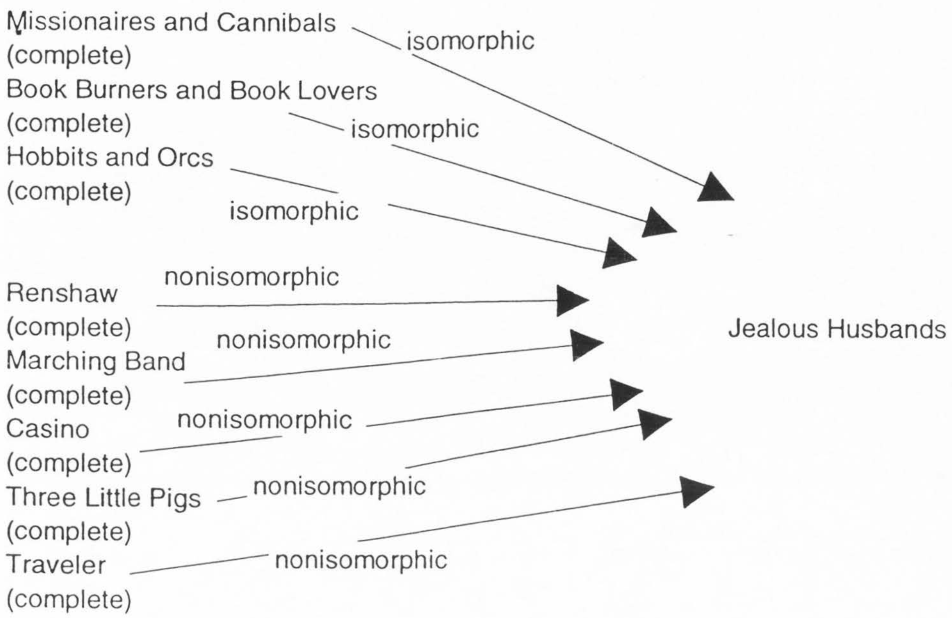

Figure 2. Relationships between problems presented during training group sessions and the jealous husbands testing problem.

generation of the solution to the target problem.

Testing problems were scored for the correctness of their solutions. Any information that could identify subjects or their group membership was removed before scoring to eliminate experimenter bias. Using the original author's correct solution strategies, solution strategies from the testing session were scored and coded by the primary researcher and an undergraduate research assistant. Each subject received a score of either zero (an incorrect solution was derived) or one (a correct solution was derived) for each testing problem. For the complete target problem, participants, whether verbally or pictorially, had to follow exactly the prescribed sequence of transportation provided by the original author (see Appendix H for the solution strategy). For the partial problem, solutions were scored as correct if they either verbally or pictorially followed the following solution strategy: The doctor could direct multiple low-intensity rays toward the tumor simultaneously from different directions, so that the healthy tissue will be left unharmed, but the effects of the low-intensity rays will summate and destroy the tumor. Solution strategies that did not use multiple low-intensity rays from different directions or that violated any of the problem rules were scored as incorrect. Approximately 10% of the data were scored by both raters and compared for interrater reliability. This process was conducted one time for the partial problem, yielding a level of 1.00, and was repeated two times for the complete problem, yielding a level of .90.

Procedure

Recruitment

Psychology 101 and 110 students were recruited for this study by being offered extra credit points and, to help ensure full participation, upon completion of the study they would be eligible to win one of four $50.00 cash prizes. In addition, to help ensure motivation and subsequent learning, participants were told that based on performance during training and testing, they may also be eligible to win one $200.00 cash prize. Once they agreed to participate, each subject was administered the problem-solving ability test to determine his/her level of expertise and was then randomly selected to participate. Participants were asked to self-select themselves into one of ten different training blocks until the target number (N = 30) was reached for each training group (N = 5). After selection was completed, the training groups were randomly assigned to one of five conditions, as presented in Table 1, with each condition represented by two training groups for a total of 30 students in each of the five conditions. (One hundred fifty students were randomly selected to participate in this study, but after participating in a portion of the training sessions, due to personal reasons, 25 students could not complete this study. To equate cell sizes, necessary to conduct chi-square analyses, 15 students were randomly dropped from the final sample, leaving 22 students in each of the five training conditions.) All participants were informed of training and testing times.

Training

All training groups attended three group meetings to equate for participation or contact time. However, the activities completed in each of these sessions were different across groups. A detailed discussion on training session activities can be found in Appendix L.

TE and LE Group Sessions

The extended training groups received problem-solving training during session one and additional practice using problem-solving skills during sessions two and three. Each session took place on a different day within a 7-day period. Although each

Table 1

Experimental Groups

	Training length	
Training group	Condensed	Extended
Control	CC	CC[a]
Teacher-generated	TC	TE
Learner-generated	LC	LE

[a]The same control subjects served as comparisons for both the extended and condensed training.

student who completed the study was eligible to win one of four $50.00 cash prizes, the one $200.00 cash prize was performance based. As such, participants were told at the beginning of the first training session that they would be asked to solve a series of problems based on information learned during sessions one and two, and that for each problem they solve correctly they would earn a chance to win a prize of $200.00.

TC and LC Group Sessions

The condensed training groups participated in activities unrelated to problem-solving processes during sessions one and two, and received problem-solving training during session three. Participants were informed of the performance-based prize in the same manner as were the extended training participants.

CC Group Sessions

The control group sessions were similar to the condensed and extended training sessions with the exception that training was replaced with simple exposure to problems. The discussion of the conditions of the performance-based prize was the same as with the condensed and extended intervention groups.

Orientation of Trainers

Training was conducted by one graduate and two undergraduate psychology students at Utah State University. These trainers were selected based on the similarity in their demeanor and teaching styles. (Here, demeanor is used to refer to one's approach to students, tone of voice, and mannerisms in general, while teaching style refers to how the trainers present course material to their students. All of the selected trainers approach students in a helpful yet unobtrusive way, are relatively soft spoken [although not the the point where students are unable to understand them], are quite respectful of students' needs and opinions, have previous teaching experience, and can utilize both traditional didactic as well as discovery teaching styles. These similarities were determined through observation of each trainer in a teaching situation.) The primary researcher facilitated an extensive and individual orientation with each trainer on familiarity with the protocols, teaching style, and training objectives. Moreover, trainers were required to train 10 undergraduate students to familiarize them with the sequence of events in the training sessions. This orientation did not include a discussion of the study's purpose in an effort to avoid any biasing effects that may occur. Thus, trainers were blind to the study's purpose.

Evidence of Treatment Fidelity

A random sample of 10% of the training sessions was videotaped in order to evaluate whether trainers presented the training elements as outlined in the protocols, and if subjects engaged in assisting one another in determining the appropriate problem-solving steps and correct solution strategies for practice problems. Videotapes were examined separately by the primary researcher and one research assistant who compared the training session against its protocol. No significant deviations from the protocol were identified, thereby indicating the training materials were consistently presented from one session to another and participant learning was not influenced by peer interactions in any session.

Testing

Approximately 1 week after training, all subjects were brought back and individually tested using two problems (i.e., the radiation problem and the jealous husbands problem). Correct solution generation to the target problems could be facilitated by students transferring to the target situation knowledge of problems and solution strategies presented during the training and control group sessions. During the testing sessions, subjects were given 20 minutes to solve each problem, and had this time expired before a solution was derived, time was called and the problem was scored as incorrect. (Previous research determined that 20 minutes for each of the target problems was ample to generate a solution strategy [Ives, 1996].)

RESULTS AND DISCUSSION

Data were first analyzed using descriptive statistics to determine the overall percentage of solvers who generated correct solution strategies to the partial and complete target problems within each group. Results are presented in Table 2.

Given the ordinal nature of the "correctness" solution data, multiple chi-square analyses were conducted for the partial and complete target problems to test the null hypothesis that group differences may have occurred by chance. Because significance testing is heavily dependent on sample size and its results may not be informative about the magnitude and practical significance of the group differences, effect sizes were also calculated. The effect size measure of standardized group mean difference as discussed by Glass, McGaw, and Smith (1981), a widely applied measure in meta-analytic studies, was used in the present study for its ease in interpretation. In translating the chi-square analysis results to the effect size measure of standardized group mean difference, Cohen's d (Cohen, 1988) was calculated using the following formulas:

$$r = \phi = \sqrt{\frac{\chi^2}{N}} \quad \text{(p. 223)} \qquad t = r\sqrt{\frac{N-2}{1-r^2}} \quad \text{(p. 76)} \qquad d = t\sqrt{\frac{1}{n_a} + \frac{1}{n_b}} \quad \text{(p. 67)}$$

By using this formula, effect sizes were calculated between each of the training and control groups and other pairwise comparisons to assist with interpretation of the chi-square findings. Interpretations of the effect size analyses are based on Cohen's (1988)

Table 2

Percentage of Subjects Correctly Solving the Two Testing Problems According to Type of Training and Length of Training

	Length of training	
Type of training	Condensed	Extended
Complete problem		
Learner-generated	18	9
Teacher-generated	18	18
Control	14	14[a]
Partial problem		
Learner-generated	9	32
Teacher-generated	14	23
Control	23	23[a]

[a]The same control participants served as comparisons for the condensed and extended teacher and learner-generated training groups.

observations of social and behavioral sciences, in which he determined an effect size of .2 was small, an effect size of .5 was medium, and effect sizes of .8 or greater were large.

Complete Target Problem Results

One of the hypotheses tested was that participating in analogical problem-solving training would augment problem-solving ability on the complete target problem. To test this hypothesis, each training group was tested against the control group. Effect size analysis results are presented in Figure 3.

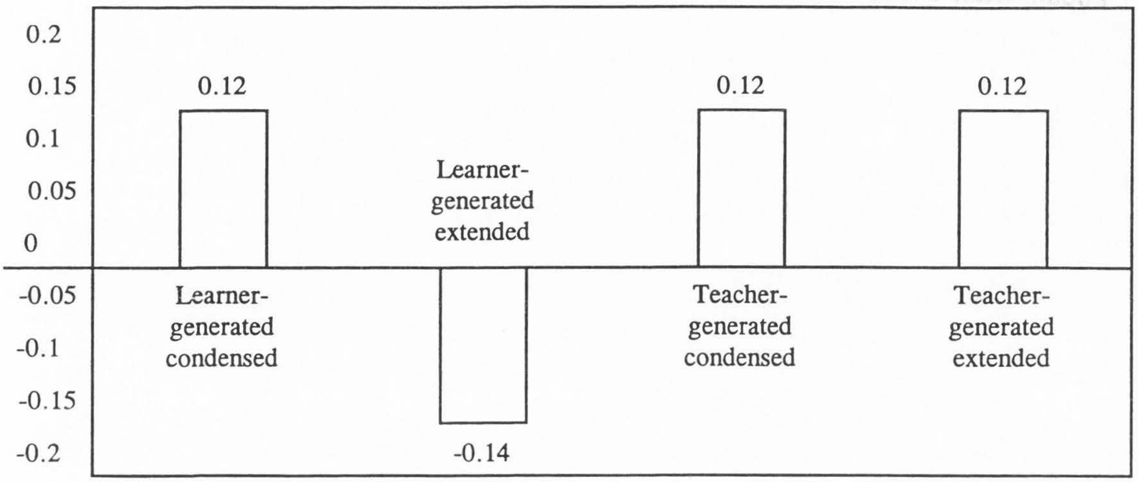

Figure 3. Complete target problem effect size analyses between the control group and each training group.

Note. A negative effect size indicates the control group outperformed the training group. (Negative effect sizes are used only in Figure 3-6 to illustrate differences between groups. The value of Cohen's d ranges from 0 to +1.0, and, as such, effect sizes discussed in the text are shown as positive rather than negative.)

No statistically significant differences were found when comparing the control and learner-generated condensed, $d = .12$, $\chi^2(1, N = 44) = .17$, $p = .68$, teacher-generated condensed, $d = .12$, $\chi^2(1, N = 44) = .17$, $p = .68$, and teacher-generated extended, $d = .12$, $\chi^2(1, N = 44) = .17$, $p = .68$, training groups. When comparing the learner-generated extended training and control groups, again, no difference was found, $d = .14$, $\chi^2(1, N = 44) = .23$, $p = .63$.

Overall, chi-square and effect analyses suggest there is no benefit for participation in analogical problem-solving training. This finding runs contrary to previous research indicating that participation in training on problem-solving processes will yield higher levels of spontaneous transfer than will mere exposure to complete analogous problems and no instruction on problem solving (Catrambone & Holyoak, 1989).

In comparison to previous studies, the present study yielded a much lower incidence of spontaneous transfer among control and condensed training participants. Control students in a similar study (Ives, 1996) yielded rates of spontaneous transfer of 40% and rates for both learner- and teacher-generated condensed training participants were 50%. In this study, rates for the three groups were significantly lower (control = 14%; learner-generated condensed = 18%; teacher-generated condensed =18%).

One reason for these differences is that previous study participants may have had prior exposure to the complete target problem. Prior exposure would have increased the likelihood of spontaneous transfer. A second explanation might be that, in the present study, participants in the condensed training and control groups were required to participate in a four-session program rather than only two sessions (i.e., a training and a testing session), as in the previous study. Here, sessions one and two were comprised of activities unrelated to analogical problem solving, training was delivered during session three, and session four consisted of testing. After participating in the first two sessions, participants may have become unmotivated to engage in the learning process during sessions three and four, thereby decreasing the likelihood of spontaneous transfer. In addition, analogical problem-solving literature suggests that novice learners will be more likely to focus on irrelevant information rather than on the relevant structural information necessary to generate a correct solution strategy (Chi & Van Lehn, 1991). In the present study, there may not have been enough instruction on the need to separate the tasks completed prior to training from the relevant material presented during the training session.

The second hypothesis tested for the complete target problem was that learner-generated extended training participants would have higher rates of spontaneous transfer than would participants in the other training groups. To test this hypothesis, each training group was compared to the learner-generated extended training group.

Comparisons of the learner-generated extended training to each of the training groups yielded the same results. In each comparison, there were no statistically significant differences: The learner-generated extended group did not differ from the learner-generated condensed group, $d = .26$, $\chi^2(1, N = 44) = .79$, $p = .38$, or teacher-generated condensed group, $d = .26$, $\chi^2(1, N = 44) = .79$, $p = .38$, or the teacher-generated extended group, $d = .26$, $\chi^2(1, N = 44) = .79$, $p = .38$.

Overall, chi-square analyses revealed no advantage for participating in the learner-generated extended training group over the other three training groups. In addition, effect size analyses indicate there is a lower rate of spontaneous transfer for the learner-generated extended group when compared to the other training groups. Thus, findings indicate that the learner-generated condensed and teacher-generated condensed and extended training groups performed at the same level, and the learner-generated extended participants had the lowest rates of spontaneous transfer.

These findings are contrary to the literature, which states that participation in a guided discovery training program will increase the likelihood of spontaneous transfer when compared to participation in a didactic training program where the processes are taught directly to the students (McDaniel & Schlager, 1990). Further, when training is comprised of multiple practice sessions (Sternberg, 1996) and is distributed over a systematic period of time (Dempster & Farris, 1990), learners should experience higher levels of spontaneous transfer in comparison to learners who participate in a limited practice, one day training session.

The lack of effect for the learner-generated extended training group may be due to a combination of factors. First, in comparison to the condensed training group, there is a higher total amount of both irrelevant and relevant information presented in the extended training sessions. The increase in information presented may have decreased the learner's ability to effectively filter irrelevant information and retrieve only irrelevant information during testing. Second, in contrast to the teacher-generated training groups, learner-generated training participants are required to actively engage in discovering the problem-solving processes. The level of activity required may have decreased the learner's motivation to engage in the learning process, thereby decreasing the likelihood that the learner would attend to relevant information presented during training. For the learner-generated extended training group, the combination of these factors may have impacted their problem-solving performance on the complete target problem. Given this, the learner-generated extended training program may not have been powerful enough to augment analogical problem-solving ability on the complete target problem.

Comparison to Previous Research

A few differences exist between the present study and previous research on providing training to augment analogical problem-solving ability. These differences may help to explain some of the findings contained in the discussion presented. In the previous research (Ives, 1996), subjects attended only sessions corresponding to sessions three and four of the present study. Thus, subjects were only presented with the training material and were not exposed to the extraneous activities provided to learners during sessions one and two of the present study. With the absence of these additional activities, learners in the previous study may have been more likely to focus only on the relevant information presented during training thereby increasing their chances of solving the problem. Also, with the addition of 2 days of training, learners in the present study may have become frustrated with the length of the training program, thereby creating a lack of motivation to learn and later apply the information presented during day three, leading to poorer performance.

While the differences between the training programs may have impacted rates of transfer, additional differences may exist that contributed to the disparity in rates of transfer. For example, although samples in the present and previous studies were similar with regard to age, gender, GPA, and year in school, students in the present study may have been less interested in the topic of problem solving. Additionally, present study participants may have had lower levels of motivation to participate in activities unrelated to their coursework. The combination of the delivery differences between the two training programs and the potential differences in learner characteristics may have impacted the learners' ability to effectively learn and apply the necessary information in the testing session.

Partial Target Problem Results

One of the hypotheses tested was that participating in analogical problem solving training would augment problem solving ability on the partial target problem. To test this hypothesis, each training group was tested against the control group. Effect size analysis results are presented in Figure 4.

For the learner-generated condensed training group comparison, a small difference was found in favor of the control participants, $\underline{d} = .38$, $\chi^2(1, \underline{N} = 44) = .16$, $\underline{p} = .21$. When comparing the learner-generated extended training and control groups, no difference was found, $\underline{d} = .20$, $\chi^2(1, \underline{N} = 44) = .46$, $\underline{p} = .50$. When considering the teacher-generated training groups, no difference was found between the teacher-generated condensed and control groups, $\underline{d} = .23$, $\chi^2(1, \underline{N} = 44) = .62$, $\underline{p} = .43$, or between the teacher-generated extended and control groups, $\underline{d} = .00$, $\chi^2(1, \underline{N} = 44) = .00$, $\underline{p} = 1.00$.

Overall, chi-square analyses revealed no effect for participating in any training group when compared to the control group. Effect size analyses further revealed negligible differences with a low to moderate advantage for the control group when compared to the condensed training groups. These findings run contrary to previous research which states that higher rates of spontaneous transfer will result from

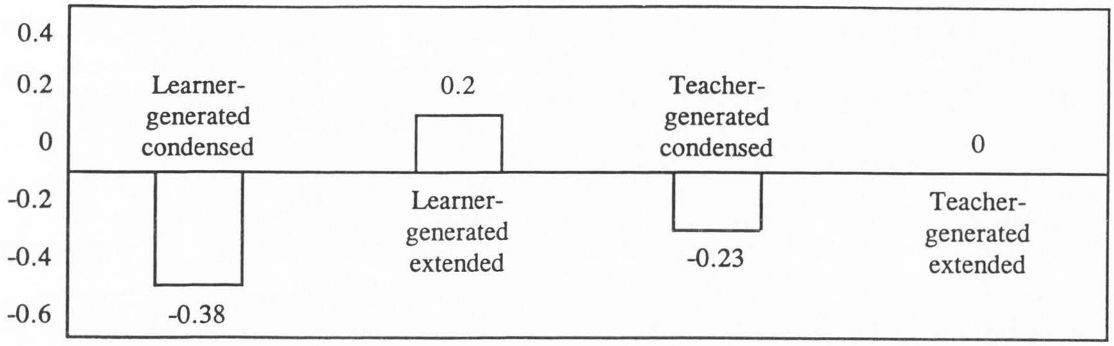

Figure 4. Partial target problem effect size analyses between the control group and each training group.

Note. A negative effect size indicates the control group outperformed the training group.

participating in problem-solving training (Catrambone & Holyoak, 1989).

In a similar study (Ives, 1996), 0% of those participating in the control group were able to spontaneously generate a correct solution strategy to the partial target problem, whereas in the present study, 23% of control group participants were able to do so. The differences in rates of transfer could be due to control group learners in this study having prior exposure to the partial target problem or its analogues. Prior exposure would increase the likelihood of spontaneous transfer, especially if the solution strategy to the partial target problem or its analogues had been learned.

In addition, 13% of teacher-generated condensed training participants and 20% of learner-generated condensed training participants in the previous study were able to spontaneously generate a correct solution strategy to the partial target problem.

Participants in the present study also yielded low rates of spontaneous transfer with rates of 14% for teacher-generated condensed training solvers and 9% for learner-generated condensed training solvers. This similarity in performance between the two studies provides support for previous research that suggests solvers will experience difficulty in generating a correct solution strategy to a target problem that has no analogous solution strategy (Antonietti, 1991). As with the complete target problem, the low rates of spontaneous transfer may be due also to a lack of motivation to engage in the learning process during the training session, and, the training programs may not have been powerful enough to yield higher levels of spontaneous transfer.

In contrast, rates of spontaneous transfer increased for teacher-generated extended (23%) and learner-generated extended (32%) training participants. As the learning literature suggests, the higher levels of performance may be due to some mediating factor, such as multiple practice sessions (Bahrick & Phelps, 1987) or spacing of learning (Anderson, 1990).

The second hypothesis tested for the partial target problem was that learner-generated extended training group participants would yield higher rates of spontaneous transfer than would participants in the other training groups. To test this hypothesis, each training group was compared to the learner-generated extended training group. Effect size analysis results are presented in Figure 5.

Comparisons of the learner-generated extended training to each of the training groups revealed low to moderate differences in favor of the learner-generated extended training group. When comparing the learner-generated extended and learner-generated

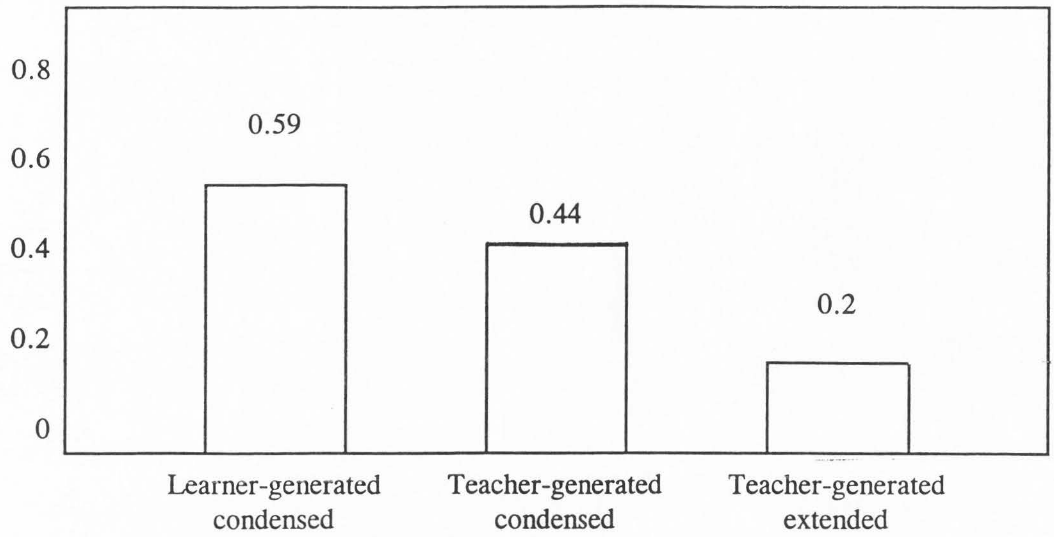

Figure 5. Partial target problem effect size analyses between the learner-generated extended training group and all other training groups.

condensed training groups, a moderate difference was noted, d = .59, $\chi^2(1, N = 44) = 3.66$, $p < .05$. The learner-generated extended and teacher-generated condensed training group comparison yielded a low to moderate difference, d = .44, $\chi^2(1, N = 44) = 2.12$, $p = .15$. Lastly, the learner-generated extended and teacher-generated extended training group comparison yielded no difference, d = .20, $\chi^2(1, N = 44) = .46$, $p = .50$, as did the comparison between teacher-generated extended and condensed training groups, d = .23, $\chi^2(1, N = 44) = .62$, $p = .43$.

Overall, chi-square analyses indicate that providing solvers with learner-generated extended training results in the highest levels of performance, especially when compared to rates of transfer among learner-generated condensed training participants. One explanation for this effect could be that learner-generated extended training participants had prior exposure to the partial target problem and its analogues.

Still, this finding supports the literature, which states that participating in multiple practice sessions (Sternberg, 1996) over an extended period of time (Dempster & Farris, 1990) will increase learning performance and the ability to recall learned information. Perhaps for a target problem that is difficult to solve due to the absence of a solution strategy, novice learners need additional practice time and they need time between sessions to assimilate the information learned.

Comparison to Previous Research

Although, as discussed in the complete target problem section, there exist several differences between the condensed and control sessions found in this and a previous study (Ives, 1996), rates of spontaneous transfer were very similar between each of the condensed training and control groups between the two studies. Thus, these differences do not appear to have impacted rates of spontaneous transfer on the partial target problem.

Complete Versus Partial Target Problem Findings

Contrary to expected outcomes, control group participants had lower levels of performance on the complete than on the partial target problem. One explanation for this finding is that participants may have had prior exposure to the partial target problem and/or its analogues. Prior exposure would have increased the likelihood of spontaneous transfer.

Learner- and teacher-generated condensed training participants yielded similarly low rates of spontaneous transfer on both target problems. This finding may be a result of lack of motivation by participants to engage in the learning process. It may also be due to the training programs not being powerful enough to augment problem-solving ability, that is, learners may need more practice over a longer period of time with solving partial and complete analogues. Still, these participants yielded slightly higher rates of transfer on the complete target problem, which is consistent with literature on providing learners with analogous solution strategies to a target problem.

Teacher-generated extended training participants had moderate levels of spontaneous transfer on both partial and complete target problems, but they had slightly higher levels of performance on the partial target problem. This finding is contrary to literature on complete and partial problems and may be due to the total amount of both relevant and irrelevant complete target problem information presented during training. Learners may not have effectively filtered the irrelevant information or retrieved the relevant information that was necessary for spontaneous transfer.

Learner-generated extended training participants had much higher levels of performance on the partial than on the complete target problem. This finding is contrary to the literature, which suggests providing learners with analogous solution strategies (presented in the complete problem) will lead to higher levels of spontaneous transfer. The disparate results may be due to a combination of factors that were part of the present study training programs, but that were absent in related research (e.g., Gick & Holyoak, 1983; Ives, 1996). First, learners were provided with more relevant and irrelevant information related to the complete target problem than they were to the partial target problem. Second, solvers in the learner-generated training programs are required to be actively involved in the learning process, which may decrease their motivation and/or ability to attend to and assimilate relevant information. The additional information combined with the need for active involvement may have negatively impacted their ability to attend to and retrieve information necessary to correctly solve the complete target problem.

Summary

In conclusion, on the complete target problem, control and condensed training participants in the present study yielded lower rates of spontaneous transfer than did learners in a similar study (Ives, 1996). In addition, the control subjects performed only slightly lower than subjects in the learner-generated condensed and teacher-generated condensed and extended training groups, all of which performed at the same level. Control subjects did, however, perform slightly better than did learner-generated extended training subjects. Furthermore, contrary to the hypothesis, learner-generated extended training subjects had the lowest rates of spontaneous transfer when compared to the other training groups.

For the partial target problem, condensed training participants yielded slightly lower and control participants had slightly higher rates of spontaneous transfer in comparison to learners in a similar study (Ives, 1996). Control subjects in the present study outperformed both learner- and teacher-generated condensed training participants and had the same rates of spontaneous transfer as teacher-generated extended training participants. As hypothesized, learner-generated extended training participants had the highest rate of spontaneous transfer, which was significantly different from the learner-generated condensed training rate. In addition, learner- and teacher-generated extended training participants had similar rates of transfer, and teacher-generated extended training learners slightly outperformed the teacher-generated condensed training learners.

CONCLUSION

When considering the impact on problem-solving ability, given the duration and type of training, findings indicate there is no advantage to participating in problem-solving training over no training, with the exception of participation in learner-generated extended training on the partial target problem. Here, solvers who participated in the learner-generated extended training were more likely than those in the condensed training to spontaneously generate a correct solution strategy to the partial target problem. This suggests that presentation and practice with multiple isomorphs over a systematically distributed period of time augment the learner's ability to retrieve and adapt relevant information needed to correctly solve a partial target problem.

However, the impact of training is diminished on the complete target problem. Findings indicate there may be no advantage to participating in a guided discovery training program comprised of multiple practice sessions over an extended period of time. Also, there may only be a slight advantage to participating in a learner-generated condensed or teacher-generated condensed or extended training program over no training. Still, these findings may be a result of prior exposure among control participants to the complete target problem and its analogues or of the amount of information presented prior to and during training, rather than a function of the potential impact of participating in training.

Limitations of the Study

Although findings indicate there may be some advantage to participating in learner-generated extended training, it is important to consider limitations that may have contributed to the lack of differential treatment effects found in this study.

The first limitation to consider is the small sample size. Findings for the learner-generated extended training and other training groups may have been impacted by sample size. A larger sample size may have yielded a greater degree of sensitivity to differences.

The second limitation worth noting is the difference in amount of total relevant and irrelevant complete analogy information in comparison to the amount of partial analogy information presented during the extended training sessions. Literature on novice learners indicates they are more likely to focus on surface and irrelevant features of base and target problems. The differences in amount of information presented may have increased the likelihood that learners would attend more to the irrelevant information presented or may have had a more difficult time filtering irrelevant information during the retrieval stage, thereby resulting in a lower rate of spontaneous transfer on the complete target problem.

A third limitation is that the irrelevant activities presented during sessions one and two of the condensed training may have impacted learners' ability to attend to relevant analogous information presented during session number three, the training session. Previous research suggests that if learners are unable to attend to relevant information during training, they will be less able to retrieve and adapt this relevant information during testing.

Another limitation is that no check was in place for prior exposure to the target problems or their analogues. Prior exposure may have increased the likelihood of spontaneous transfer.

A final limitation is that the duration of the training may not have been long enough or intense enough to effect high rates of spontaneous transfer. As the literature on spacing and practice effects does not prescribe the amount of practice or duration of time between sessions, it is unclear whether this training met the learning needs of the participants. Perhaps a training program that included more intense practice sessions with a longer amount of time between sessions may have yielded higher rates of spontaneous transfer.

Implications of Findings

The results of this study suggest that after participating in a distributed learning training program with multiple practice opportunities, novice solvers may be better able to spontaneously generate a correct solution strategy to a problem for which they had no analogous solution strategy. This finding suggests that researchers may be able to increase spontaneous transfer through involving learners in either guided discovery or didactic problem-solving training programs that are provided over a distributed period of time and that include several practice opportunities. However, as some of the findings did not match the analogical problem-solving literature, there is still a great deal to learn about what needs to be included in problem-solving training to achieve high levels of spontaneous transfer.

Findings from this study extend beyond the laboratory. That is, when presenting new and complex lessons and problems either through didactic instruction or guided discovery, teachers who provide multiple opportunities to practice the newly learned processes over a systematically distributed period of time may witness an increase in their students' problem-solving ability. In addition, through these methods, students may experience a decrease in reliance on teachers and peers and an increase in critical thinking, self-sufficiency, and ultimately in academic performance. Still, this study's findings indicate teachers may need to provide direct instruction or perhaps more practice on how to attend to the structural elements of a problem and on how to filter irrelevant surface features. Also, as the literature on practice and spacing effects, as related to analogical problem solving, does not provide prescribed parameters for instructors, teachers may want to include in their instruction checks for understanding and ability to determine the length of time between sessions and total amount of practice necessary for spontaneous transfer.

Future Studies

Findings from this study suggest that future studies on analogical problem solving among novice learners should continue to focus on the facilitating effects of providing multiple practice sessions and distributed learning and, in the case of partial target problems, involving the learner in the development of problem-solving processes. Future studies should also explore the total training time, amount of practice, and duration of time between sessions needed to increase levels of spontaneous transfer. While in the present study three training sessions positively impacted rates of spontaneous transfer on the partial target problem, extending the duration of each training session, the amount of time between training sessions, and the total training time may further increase the incidence of spontaneous transfer on partial as well as on complete target problems. To counteract the limitations previously discussed, the following are additional areas on which future studies may wish to focus.

Findings indicate that participants had a more difficult time generating a correct solution strategy to the complete target problem than for the partial target problem. Given this difference in rate of spontaneous transfer, researchers should examine what may have impacted the learners' ability to effectively transfer and apply information to the target problem. Two possibilities to explain what may have impacted solving rates were identified in this study. First, learners were provided with a higher total amount of both relevant and irrelevant information analogous to the complete target problem than to the partial target problem. Additional research should focus on analyzing how much information is too much information to provide during learning sessions. A second possibility is that learners may employ different problem-solving strategies when learning and applying complete analogous problem information. Further research should also include a measure of the actual strategies employed by novice solvers.

The findings of the present study indicated that learners might have had prior exposure to the base and target problems, which would increase the likelihood that they would generate a correct solution strategy. Given this, future studies should investigate the impact prior exposure has on spontaneous transfer. Additionally, as condensed training participants yielded lower rates of spontaneous transfer on the partial target problem than extended training participants, researchers should examine the effect of providing irrelevant activities prior to training and on providing additional instruction on how to filter irrelevant material.

Lastly, it is hoped that researchers will both replicate and extend this research to samples from broader populations. These actions may both increase the confidence placed in the findings as well as the study's generalizability, thereby further increasing our knowledge about analogical problem solving.

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APPENDICES

Appendix A.

Participant Consent Form

Informed Consent Form

I, ________________________, agree to participate in the problem-solving project, which is conducted by Dune Ives, Ph.D. candidate. My participation is voluntary and will involve approximately four (4) hours of commitment and I will receive five (5) extra credit points toward my course grade for completing the entire project. I understand that I may discontinue my participation at any time without penalty provided that I notify the experimenter of my decision.

I understand that the purpose of this research is to investigate how people problem solve, and my involvement will consist of reading verbal problems and providing solutions to these problems. There are no discomforts, stresses, or risks involved. The benefits I can expect from my participation include information on how well I problem solve and how to become a better problem solver. The results of my participation, including problem solving ability, will remain confidential and will be identified only by number code thereby assuring anonymity of my responses.

At the conclusion of my participation, I will be given an explanation of the experiment. I understand that I can contact Ms. Ives or Dr. Lani Van Dusen at any time either by phone or in writing to the addresses listed below for answers to pertinent questions about the research and my rights as a participant.

________________________	____________	__________________
print your name here	today's date	daytime telephone number
________________________	____________	__________________
sign your name here	e-mail address	evening telephone number

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Appendix B.

Demographic Information Questionnaire

For the following questions, please either write in a response in the space provided or check the appropriate box (please select only one answer for each question).

Q1. Name ________________________
(last, first, middle initial)

Q2. Gender

- ☐ Male
- ☐ Female

Q3. Year in school

- ☐ Freshman (0-44 credits)
- ☐ Sophomore (45-89 credits)
- ☐ Junior (90-134 credits)
- ☐ Senior (135 + credits)
- ☐ Other ________________ (please specify)

Q4. Current age _____________

Q5. Current total GPA ________

Q6. Total ACT score: ________

Q7. Is English your first language?

- ☐ yes
- ☐ no ___ first language ____________________ (please specify)

Q8. Social Security number: _______________

Appendix C.

Problem-Solving Ability Test

Three Monsters

Three extraterrestrial monsters were holding three crystal globes. Because of the quantum-mechanical peculiarities of their neighborhood, both monsters and globes come in exactly three sizes with no others permitted: small, medium, and large. The medium-sized monster was holding the small globe, the small monster was holding the large globe; and the large monster was holding the medium-sized globe. Since this situation offended their keenly developed sense of symmetry, they proceeded to transfer globes from one monster to another so that each monster would have a globe proportionate to his own size. Monster etiquette complicated the solution of the problem since it requires: 1) that only one globe may be transferred at one time, 2) that if a monster is holding two globes, only the larger of the two may be transferred, and 3) that a globe may not be transferred to a monster who is holding a larger globe. By what sequence of transfer could the monsters have solved this problem?

Solution:
The small monster passes the large globe to the large monster. The medium monster passes the small globe to the small monster. The large monster passes the large globe to the medium monster, and then passes the medium globe to the small monster. The medium monster passes the large globe to the large monster. The small monster then passes the medium globe to the medium monster. Now, the large monster has the large globe, the medium monster has the medium globe, and the small monster has the small globe.

The Cord Problem

Suppose you are in a room where two cords of equal length are hung from the ceiling. The two cords are of such a length that when you hold one cord in one hand, you cannot reach the other cord. Your task is to tie the ends of these cords together. To help you in this task, you may use any of the objects listed below, which are also in this room: weights, poles, clamps, pliers, extension cords, tables, chairs. How will you complete this task?

Solution:
Tie a weight to one cord and swing it so it becomes a pendulum. The other cord can then be brought toward the center, the swinging cord can be caught as it approaches the midpoint, and then the two cords can be tied together.

The Artificial Lake

An engineer plans the construction of an artificial lake to produce electric energy. According to his first plan, a unique wide canal collects water coming from a valley and conveys it into the lake. However, the engineer realizes that the capacity of the lake is not sufficient to produce the needed amount of energy. However, it is not possible to widen the lake because there are no free areas around it. What could the engineer do to increase the capacity of the lake?

Solution:
To avoid this mishap, the engineer elaborates a second plan. According to this plan, the lake must be deepened so that it contains a higher amount of water.

Appendix D.

Control Group Protocol

[Begin this training session by taking roll call!!]

I. Introduction

Hello and thank you for agreeing to participate in our problem-solving study. My name is _________________ and I will be your trainer today. Let me begin first by telling you a little about myself. I am in the Psychology program here at Utah State University, and am currently in my ______ year of the program.

Dune Ives, the project coordinator asked me to give you a few pointers on how to become better problem solvers.

As you have been told, this training is the third day of our four-part study. The fourth part will consist of testing your problem solving ability in a separate section for which you should have already signed up.

I have a separate piece of paper for each of you that list the date, day, time, and room of your fourth and final session that I will hand out to you at the end of our session today.

Today I am going to give you a series of nine problems and have you attempt to solve them.

As an added bonus for your participation in this entire study, you will have the opportunity to win up to $225.00 in cash and prizes.

First, as Dune has told you, you may win one of four $25.00 gift certificates just for completing this study.

Second, depending on your performance during this training session and the final testing session you will earn up to four chances for a grand prize of $200.00. For each qualifying problem that you solve correctly today and during the testing session you will earn one chance to win $200.00.

As an example, if you solve one of the two problems correctly today and two problems during the testing session, you will have three chances to win the grand prize. So, the more you pay attention and learn, the more chances you will have to win. As I present problems to you today, I will indicate on which problems you may earn chances and we will correct your solutions together.

Are there any questions before we get started?

[allow only a couple of minutes for questions and answers]

Great, let's get started.

II. Practice

First, let me tell you how this will work. I will time you as you attempt to solve the problems and may call time before you complete a problem. On occasion, I may provide you with the completed answer to help you think about these problem solving strategies. It is important that when solving each of these problems you only use the information provided in the problem description.

Each problem will be handed out to you on separate sheets of paper on which you should write your solution. Also, please put your name on the back of each paper I hand out to you.

The first problem I want you to solve is the general problem.
[hand out problem and read through out loud]

Go ahead and begin.

[call time after 1 minute]

Here is a second problem, the book lovers and book burners problem.

[hand out problem and read through out loud]

Please begin solving this problem.

[call time after everyone has finished or when five minutes has passed, whichever comes first]

Okay, for those of you who did not have enough time to finish this problem let me give you the answer.

[put up book lover problem solution]

Now try the parade problem.

[hand out problem and read out loud]

Begin.

[call time after 1 minute]

The next problem is the hobbits and orcs problem.

[hand out problem and read out loud]

Begin solving this problem.

[call time after everyone has finished or when five minutes has passed, whichever comes first]

Okay, for those of you who did not have enough time to finish this problem let me give you the answer.

[put up hobbits and orcs problem solution and read out loud]

Lets have you try the fireman problem this time.

[hand out problem and read out loud]

Go ahead and start.

[call time after 1 1/2 minutes]

Our next problem, the King and poison cups, is the first problem on which you may earn a chance to win the $200.00 prize if you generate the correct solution.

[hand out problem and read out loud]

Begin.

[call time after everyone has finished or when five minutes has passed, whichever comes first]

Now, let's see how everyone did. Switch your paper with the person sitting next to you. I will read through the correct solution and you should score the solution given to you as either correct or incorrect by writing the word "correct" or "incorrect" in the upper right hand corner of the paper.

[put up King and poison cups solution and read through]

How about trying the Marching Band problem

[hand out problem and read out loud]

Please begin.

[call time after everyone has finished or when five minutes has passed, whichever comes first]

Just two more problems and we are all through.

Here is the missionaries and cannibals problem.

[hand out problem and read out loud]

Begin solving this problem.

[call time after everyone has finished or when five minutes has passed, whichever comes first]

Okay, for those of you who did not have enough time to finish this problem let me give you the answer.

[put up missionaries and cannibals problem solution and read out loud]

Finally, here is the traveler liar/truth teller problem, on which you may earn another chance to win the $200.00 prize if you solve it correctly.

[hand out problem and read out loud]

Begin solving this problem.

[call time after everyone has finished or when five minutes has passed, whichever comes first]

Okay, let's have everyone switch papers with the person sitting next to you and we will score your solution as either correct or incorrect.

[put up traveler liar/truth teller solution and read out loud]

III. Conclusion

That concludes the third part of our problem-solving study. I want to thank each of you for participating. As I said before, I have a piece of paper for each of you that lists the day, date, time, and room of your final session.

Remember, it is extremely important that each of you participate in the fourth part, so please look over these days and times to make sure you can attend.

As Dune may have told you, you will receive extra credit points when you complete the study, so not only are you helping us out--you receive something in return! And, as I told you earlier, you may win up to $225.00 in cash and prizes for completing the study and for solving problems correctly.

Today, I gave you two chances to win the $200.00 cash prize, and during the final testing session you will have two more chances to win.

One final note, during the next few weeks it is vital that you do not discuss this training, or the testing you will complete, with anyone in this group or anyone else in your Psychology class.

Again, thank you for coming.

If there any no more questions you are free to go after you have picked up your paper and have made sure that your name is written on the back of each paper I handed out to you.

[collect all handouts at this time and let them leave only after they have confirmed their testing date and time with you and you have given them their individual confirmation slips]

Appendix E.

Teacher-Generated Condensed Training Protocol

[Begin this training session by taking roll call!!]

I. Introduction

Hello and thank you for agreeing to participate in our problem-solving study. My name is ________________ and I will be your trainer today. Let me begin first by telling you a little about myself. I am in the Psychology program here at Utah State University, and am currently in my ______ year of the program.

Dune Ives, the project coordinator asked me to give you a few pointers on how to become better problem solvers.

As you have been told, this training is the third day of our four-part study. The fourth part will consist of testing your problem solving ability in a separate section for which you should have already signed up.

I have a piece of paper for each of you that lists the day, date, time, and room of your fourth and final session that I will hand out at the end of our session today.

First, let me give you a brief overview of what I will be covering today. As I said before, I will teach you about specific types of problems and problem solving strategies, and then I will put your knowledge to the test and let you practice what I have taught you.

As an added bonus for your participation in this entire study, you will have the opportunity to win up to $225.00 in cash and prizes.

First, as Dune has told you, you may win one of four $25.00 gift certificates just for completing this study.

Second, depending on your performance during this training session and the final testing session you will earn up to four chances for a grand prize of $200.00. For each qualifying problem that you solve correctly today and during the testing session you will earn one chance to win $200.00.

As an example, if you solve one of the two problems correctly today and two problems during the testing session, you will have three chances to win the grand prize. The last two problems I have you solve today will be the problems with which you may win chances if you solve them correctly.

What will be important to remember is that I will be teaching you things during this training session that you will need to remember to be able to correctly solve problems today and during the final testing session. So, the more you pay attention and learn, the more chances you will have to win.

Are there any questions before we get started?

[allow only a couple of minutes for questions and answers]

Great, let's get started.

II. Problem Solving Strategies

There are several ways to solve problems.

The first method is called **trial and error**.

In this method, you attempt to solve the problem using one method, evaluate your efforts, and either solve the problem, try a new method, or stop trying because you have run out of methods.

Let's work through an example that can be solved through trial and error.

[put Tower of Hanoi 3-disk problem up on the overhead and read it out loud]

First, you might suggest moving disk A to peg two, then disk B to peg two. Upon evaluation of this solution, you discover that this is impossible since you cannot move a larger disk on top of a smaller disk.

Okay, so let's try moving disk B to peg three and disk C to peg two. Again, this solution also will not work.

So that is how trial and error works. You find one approach, try it, and when it no longer works go on to the next approach or stop trying because you have exhausted your methods.

Let's take a look at the correct solution strategy for the Tower of Hanoi 3-disk problem.

[put up Tower of Hanoi 3-disk problem solution strategy and read out loud]

Another problem that you could use the trial and error method with is the parade problem.

[put up parade problem on the overhead and read it out loud--make sure students do not generate any solutions and shout them out]

First, you might suggest that the general put the parade on television. Upon evaluation of this solution, you discover that this is impossible since the fortress was surrounded by farms and villages and the chances of them having tv's is very slim.

Okay, so now you might suggest having the army walk on very high stilts in the parade so that everyone could see them above the trees, but upon evaluation of this solution you find that this may not be the best solution.

Again, that is how trial and error works. You find one approach, try it, and when it no longer works go on to the next approach or stop trying because you have exhausted your methods.

A second problem solving strategy is called **working backwards**, in which you identify your goal state, that is, what the problem will look like when it is solved. You continue to work backward from this state until you have reached the beginning.

Here is an example of a problem that might require using working backwards.

[put poker problem up on the overhead and read it out loud--make sure students do not generate any solutions and shout them out]

In this problem, you should first identify what the goal is--to find out what the original stake of each player was and begin to work backwards from the last game--game number three and continue until you have figured out what happened in the second and first games.

Another strategy is called **working forward** in which you either break the problem into smaller sub-goals and provide a means of solving each sub-goal, or you identify the initial state of the problem (what information you have) and its final goal state (what the problem should end up looking like) and work to decrease the difference between the two.

Again, let's look at an example of a problem in which you might use working forward.

[put general problem up on the overhead and read it out loud]

Here, we know that the general must attack the fortress with his entire army and that only small bodies of men could pass over the planted mines safely. Thus, we have identified the initial state of the problem. We also know that the final goal is to determine what the general must do to capture the fortress without detonating the mines, and, as a result, blowing up the road and destroying many neighboring villages.

Next, we would begin to decrease the differences between where the general is and where he must go with his army. Or, we could break up the problem into subgoals--the first being sending his men over the mines safely and the second being attacking the fortress--and begin by solving each subgoal.

A second problem you could use the working forward method with is Renshaw problem.

[put up the Renshaw problem on the overhead and read it out loud]

Here, we know that the Renshaw's have determined that they will buy six of each kind of vegetable to plant in their garden--thus, we have identified the initial state of the problem. We also know that the final goal state is to determine what would be the fewest total number of plants the Renshaws could buy that would fill each row of their garden evenly if they were to buy six of each kind of vegetable.

From here, we would work to decrease the difference between what the Renshaws have decided on and what they still need to know about the fewest total number of plants to buy.

Let's see how the correct solution strategy is developed when we use the working forward method.

[put up Renshaw solution on overhead and read out loud]

A third problem you could use the working forward method with is the fireman problem.

[put up fireman problem on the overhead and read it out loud--make sure students do not generate any solutions and shout them out]

Here, we know that the fireman must put out the fire with a large amount of water. Thus, we have identified the initial state of the problem. We also know that the final goal is to determine how best to throw a large amount of water onto the fire using only a limited amount of buckets.

Next, we would decrease the difference between the fireman's present situation and what he must do to put out the fire. Or, we could break up the problem into subgoals--the first being organizing his men to use a small number of buckets and the second being putting out the fire--and begin by solving each subgoal.

Finally, one of the most effective strategies is problem solving by **analogy**.

In this case, you would search for solutions to problems similar (that is, analogous) to the one you are presented with, and test whether this solution would be appropriate for the present problem. There are several steps you should consider when solving by analogy.

To illustrate how these steps work, let's take a look at the Tower of Hanoi 4-disk problem.

[hand out problem and read it out loud]

Does this appear to be a difficult problem to solve? To most, this would be rather difficult to solve, no matter how much time you are given to generate a correct solution strategy.

So, let's go over the steps you should take when solving a problem by analogy and you might see how to make the Tower of Hanoi 4-disk problem easier to solve.

The first step is to identify the goal of the current problem you are trying to solve, which again is the information you need to understand to solve the problem. In this case, the goal is to move all four disks from peg one to peg three. You would then identify the objects in the problem--here the objects are the four disks of different sizes and three pegs.

Next, identify the problem's constraints--only the top disk can be moved and it can never be placed on a smaller peg.

Then you would want to search for and retrieve from your memory problems similar to the one you are attempting to solve.

Here is a list of the problems you have been exposed to today.

[put up list of analogies and read it out loud]

From this list, we find that you have been exposed to an analogous problem, the Tower of Hanoi 3-disk problem, so you should recall what you remember from that problem. Then, you would want to compare the objects and constraints in your current problem and the problem you retrieved. This allows you to determine how similar the problems are, and we see that these two problems are quite similar.

[put up correspondence A on the overhead and read the comparisons out loud]

After comparing the problems, you would apply the analogous solution or strategy to your current problem and evaluate it for its appropriateness.

Normally, you would do this by using analogies you have been exposed to before, but for right now I will provide you with an analogy for each problem to be solved.

For the remaining problems you will be given, I want you to practice problem solving using the analogical method.

III. Practice

Here is the book burners and book lovers problem.

Try to solve it by the analogical problem solving method.

[hand out problem and read it out loud]

Use the following analogy to help you solve the book burners and book lovers problem.

[hand out cannibal problem and read it out loud]

If you were asked to solve the book burner problem and you did so by the analogical problem solving method, the most helpful analogy would be one that was similar to your problem, and in which both the goal state and the strategy or solution were provided to you. The cannibal problem does exactly that.

Thus, your first step in solving the book burners problem would be to identify the goal of the problem. Take a minute to write down the goal state on the piece of paper labeled "book burner."

[give them about one minute to complete this task]

Doing this, you find that the goal state is to determine how to get all six people across the river in such a way that all the books are left in tact.

Next, you should identify the objects and constraints of the target problem--the book burner problem.

Once you have completed this you should look for a problem that is similar to your target problem, which in this case is the cannibal problem.

Next, you would compare the objects and constraints in the book burner and cannibal problems.

Take a minute to do this now.

[give them about three minutes to complete this task]

By doing so, you find that there are three book burners and three book lovers just as there are three cannibals and three missionaries, the boat can only hold two people in each problem, and the book burners and cannibals can never outnumber the book lovers and missionaries.

The third step would be to apply the strategy or solution from the cannibal problem to the book burners problem.

Let's see if this works. Using the paper labeled "book burners," take a few minutes and try to solve the book burners problem.

[give them 5 minutes to solve the problem, or call time sooner if everyone finishes before 5 minutes is up]

Okay, let's see how your solution compares to the correct solution to the book burners problem.

[put up book burner solution and read it out loud]

So, we see that using the cannibal problem would be an appropriate analogy to the book burner problem.

Although this next problem, the hobbits and orcs problem, is very similar to the first two problems, it is not as similar to the next problem, the men and boys problem. More specifically, it is similar but there are some differences.

[hand out both problem and read it out loud]

[when finished, put up Correspondence B overhead]

In this problem, there are 11 objects instead of six, the problem goals are slightly different (men and boys problem involve more objects to transport across the river and you need to determine the number of times the boat must cross the river), and the constraints are slightly different (the boat can carry either one man or the two boys). Thus, while these appear are similar to each other, they are considered to be only somewhat similar.

Having an similar analogy is more helpful to you when solving a problem by the analogical strategy, but depending on the similarity between two problems a somewhat similar analogy may also be helpful.

Using the hobbits and orcs problem as an analogy, let's try to solve the men and boys problem.

The first step would be to determine what our final goal state is, which in this case is to determine the number of trips it would take to cross the river and successfully transport all 11 persons across the river.

Next, you would represent both the problem and an appropriate analogy, in this case the hobbits and orcs as we have just done.

[put up Correspondence B overhead again]

After this step you would retrieve the hobbits and orcs solution strategy and apply it to the men and boys problem.

[put up hobbits and orcs solution on the overhead]

Using the paper labeled "men and boys," take a few minutes to solve the men and boys problem.

[give them 5 minutes to solve the problem]

Okay, let's look at the correct solution to the men and boys problem.

[put up men and boys solution on the overhead and read it through]

So, the hobbits and orcs problem would be an appropriate analogy to the men and boys problem even though they are not completely similar in nature.

So, when solving a problem, you would first want to retrieve a complete similar problem and see if it helps you solve your current problem.

However, if you don't have a complete similar problem, you would then want to try a somewhat similar problem. You may find that a somewhat similar problem would be helpful to you when solving your current problem.

Another important factor when solving by analogy is whether the analogy itself is complete or partial.

A complete problem is one that provides you with the initial and final goal states, objects and constraints, strategies, and a solution. The cannibal and hobbits problems we just encountered are complete problems.

If these problems had not provided us with all this information they would have been called partial problems.

Both types of problems can be used as analogies, but the most helpful are the complete problems. As you can probably guess, it would have been more difficult to solve the book burner problem using the cannibal problem as an analogy had it not provided a solution, but just knowing the general strategy would have been helpful.

Let's see how using a partial problem may assist you.

Let's try solving this next problem, the Trump Suit problem using its corresponding partial analogy, the Wine Merchants problem.

[hand out Trump problem and Wine Merchants problem and read through each]

This is the first problem with which you may earn another chance to win the $200.00 prize by generating a correct solution strategy.

First, take a minute to read through each problem while noticing similarities between their problem goals, objects, and constraints, and then attempt to solve the Trump suit problem using the piece of paper labeled "trump suit."

[give them 5 minutes to solve the Trump suit problem]

Okay, let's go through these together. You probably noticed that both problems involve similar problem goals (to travel through water to the rich man's dwelling with the requested item before sunset), objects (one rich man and two other men), and similar constraints (the water proves to be a barrier to the travel). However, you may have noticed that the Wine Merchants did not provide the solution, that is it is a partial problem.

Let's see how your solution compares to our correct solution strategy.

First, let's switch papers again and go through these together. Write either "correct" or "incorrect" in the top right hand corner of the paper you are correcting.

[put up Trump suit problem solution on the overhead and read through].

While this is our correct solution, there are several solutions that may work. Also, even though the Wine Merchants problem did not provide a solution strategy, it may have been helpful to you in determining the best strategy to use based on what you think may have worked with the Wine Merchants.

What Dune will do is evaluate each solution strategy to the Trump Suit problem and determine whether or not it earns a chance at the $200.00 prize even though it may not be the same solution that I just presented to you.

The third problem to be solved is the marching band problem.

[hand out problem and read out loud]

The marching band problem is the second problem with which you may earn a chance to win the $200.00 prize if you solve it correctly.

You have already seen an analogy to the marching band problem earlier in today's session--the Renshaw problem.

Take a minute to recall similarities between the marching band and Renshaw problem goals, objects, and constraints, and attempt to solve the marching band problem using the piece of paper labeled "marching band."

[give them 5 minutes to solve the problem or call time sooner if everyone finishes before time is up]

Okay, let's go through these together. You probably noticed that both problems involve similar problem goals (arranging objects into rows or groups so that there were the same number of objects in each row or group or that there were no objects left over), object groups (an undetermined number of plants and band members), and similar constraints (an extra person and two extra plants that were not originally taken into consideration).

So to summarize, the band members are like plants, the rows and columns of band members are like kinds of plants, and the number of band members per row or column is like the number of plants of each kind.

Seeing these similarities, you could simply apply the strategy from the Renshaw problem to see if it is appropriate and adequately solves the marching band problem.

Switch papers with your neighbor and let's score these solutions as either "correct" or "incorrect" again writing "correct" or "incorrect" in the top right hand corner of the paper.

[put up overhead of marching band problem solution]

As you can see, you must apply the formula of finding the least common multiple of the divisors from the marching band problem (12, 8, and 3), which equals 24, 48, 72, 96, etc., add the constant remainder of 1 (extra band member) to each LCM (25, 49, 73, 97, etc.) and find the LCM which can be evenly divisible by 5 (the fourth suggestion on number of band members per row). This LCM is 145.

So, as with the problems we have already been exposed to, the marching band problem can be solved by using the solution from the Renshaw problem.

One final point is that analogies come by recalling previously seen problems and they are not necessarily always given to us at the time of problem solving as you just saw.

So the first best step, after identifying the problems' goal, is to ask yourself "have I ever seen a problem like this before?" and retrieve the relevant information from memory.

You all did a really good job at following the analogical problem solving process. Let us recap this process.

First, you determine the problems' goal, second, you looked at the problem's objects and constraints, third, you note whether you had experienced a similar problem and you recall it, fourth, you identify any similarities and differences between the problem and its analogy, and fifth, you attempt to apply the analogical strategy and solution to the problem you are solving.

III. Conclusion

That concludes the third part of our problem-solving study. I want to thank each of you for participating. As I said before, I have a piece of paper for each of you that lists the day, date, time, and room of your fourth and final session..

Remember, it is extremely important that each of you participate in the fourth part, so please look over these days and times to make sure you can attend.

As you have been told, you will receive extra credit points when you complete the study, so not only are you helping us out--you receive something in return!

And, as I told you earlier, you may win up to $225.00 in cash and prizes for completing the study and for solving problems correctly.

In addition, you will have two more chances at winning the $200.00 grand prize at the next session.

One final note, during the next few weeks it is vital that you do not discuss this training, the testing you will complete, or your chance to win the grand prize of $200.00 with anyone in this group or anyone else in your Psychology class.

Again, thank you for coming.

If there any no more questions you are free to go after you have picked up your paper and have made sure that your name is written on the back of each paper I handed out to you.

[collect all handouts at this time and let them leave only after they have confirmed their testing date and time with you and you have given them their individual confirmation slips]

Appendix F.

Teacher-Generated Extended Training Protocol

Day One
[Begin this training session by taking roll call!!]

I. Introduction

Hello and thank you for agreeing to participate in our problem-solving study. My name is ________________ and I will be your trainer today. Let me begin first by telling you a little about myself. I am in the Psychology program here at Utah State University, and am currently in my ______ year of the program.

Dune Ives, the project coordinator asked me to give you a few pointers on how to become better problem solvers.

As you have been told, this training is the first day of our four-part study. The second and third days will consist of similar training, while the fourth day will consist of testing your problem solving ability in a separate section for which you should have already signed up.

I have a piece of paper for each of you that lists the day, date, time, and room of your next session that I will hand out to you at the end of our session today.

First, let me give you a brief overview of what I will be covering today. As I said before, I will teach you about specific types of problems and problem solving strategies, and then I will put your knowledge to the test and let you practice what I have taught you.

As an added bonus for your participation in this entire study, you will have the opportunity to win up to $225.00 in cash and prizes.

First, as Dune has told you, you may win one of four $25.00 gift certificates just for completing this study.

Second, depending on your performance during the third training session and final testing session you have the chance to earn up to four chances for a grand prize of $200.00. For each qualifying problem that you solve correctly on the third day of training and during the testing session you will earn one chance to win $200.00.

As an example, if you solve one of the two problems correctly on day three and two problems during the testing session, you will have three chances to win the grand prize.

What will be important for you to remember is that I will be teaching you things during this training session and your second training session that you will need to remember to be able to correctly solve problems during sessions three and four. So, the more you pay attention and learn, the more chances you will have to win.

Are there any questions before we get started?

[allow only a couple of minutes for questions and answers]

Great, let's get started.

II. Problem Solving Strategies

There are several ways to solve problems.

The first method is called **trial and error**.

In this method, you attempt to solve the problem using one method, evaluate your efforts, and either solve the problem, try a new method, or stop trying because you have run out of methods.

Let's work through an example that can be solved through trial and error.

[put Tower of Hanoi 3-disk problem up on the overhead and read it out loud]

First, you might suggest moving disk A to peg two, then disk B to peg two. Upon evaluation of this solution, you discover that this is impossible since you cannot move a larger disk on top of a smaller disk.

Okay, so let's try moving disk B to peg three and disk C to peg two. Again, this solution also will not work.

So that is how trial and error works. You find one approach, try it, and when it no longer works go on to the next approach or stop trying because you have exhausted your methods.

Let's take a look at the correct solution strategy for the Tower of Hanoi 3-disk problem.

[put up Tower of Hanoi 3-disk problem solution strategy and read out loud]

A second problem solving strategy is called **working backwards**, in which you identify your goal state, that is, what the problem will look like when it is solved. You continue to work backward from this state until you have reached the beginning.

Here is an example of a problem that might require using working backwards.

[put poker problem up on the overhead and read it out loud--make sure students do not generate any solutions and shout them out]

In this problem, you should first identify what the goal is--to find out what the original stake of each player was and begin to work backwards from the last game--game number three and continue until you have figured out what happened in the second and first games.

Another strategy is called **working forward** in which you either break the problem into smaller sub-goals and provide a means of solving each sub-goal, or you identify the initial state of the problem (what information you have) and its final goal state (what the problem should end up looking like) and work to decrease the difference between the two.

Again, let's look at an example of a problem in which you might use working forward.

[put three little pigs problem up on the overhead and read it out loud--make sure students do not generate any solutions and shout them out]

Here, we know that the three little pigs need to move their house to escape the terror of the big bad wolf. Thus, we have identified the initial state of the problem. We also know that the final goal is to determine how the three little pigs, who are not strong enough to move their house on top of the big hill, will be able to move their house.

Next, we would begin to decrease the differences between where the house is now and where the house must go to. Or, we could break up the problem into subgoals--the first being escaping the wrath of the big bad wolf and the second being moving the house on top of the big hill--and begin by solving each subgoal.

Finally, one of the most effective strategies is problem solving by **analogy**.

In this case, you would search for solutions to problems similar (that is, analogous) to the one you are presented with, and test whether this solution would be appropriate for the present problem. There are several steps you should consider when solving by analogy.

To illustrate how these steps work, let's take a look at the Tower of Hanoi 4-disk problem.

[hand out problem and read it out loud]

Does this appear to be a difficult problem to solve? To most, this would be rather difficult to solve, no matter how much time you are given to generate a correct solution strategy.

So, let's go over the steps you should take when solving a problem by analogy and you might see how to make the Tower of Hanoi 4-disk problem easier to solve.

The first step is to identify the goal of the current problem you are trying to solve, which again is the information you need to understand to solve the problem. In this case, the goal is to move all four disks from peg one to peg three. You would then identify the objects in the problem--here the objects are the four disks of different sizes and three pegs.

Next, identify the problem's constraints--only the top disk can be moved and it can never be placed on a smaller peg.

Then you would want to search for and retrieve from your memory problems similar to the one you are attempting to solve.

Here is a list of the problems you have been exposed to today.

[put up list of analogies and read it out loud]

From this list, we find that you have been exposed to an analogous problem, the Tower of Hanoi 3-disk problem, so you should recall what you remember from that problem. Then, you would want to compare the objects and constraints in your current problem and the problem you retrieved. This allows you to determine how similar the problems are, and we see that these two problems are quite similar.

[put up correspondence A on the overhead and read the comparisons out loud]

After comparing the problems, you would apply the analogous solution or strategy to your current problem and evaluate it for its appropriateness.

Normally, you would do this by using analogies you have been exposed to before, but for right now I will provide you with an analogy for each problem to be solved.

For the remaining problems you will be given, I want you to practice problem solving using the analogical method.

III. Practice

Okay, let's begin with analogy set number one.

[hand out set one to each student]

Please read through each problem and solution as I hand these out but do not write on these forms.

[wait until each student has read through all three analogies]

Now, using the analogical problem solving I described for you, let's try to solve the first practice problem.

[hand out casino problem and read out loud]

Remember, when solving problems using analogies, the first step is to identify the goal of the current problem you are trying to solve, which again is the information you need to understand to solve the problem. In this case, the goal is to determine which box contains which type of gambling chip.

Next, you identify the objects in the problem--here, the objects are the different boxes and the gambling chips of varying amounts.

Then you identify the constraints of the problem--here, the problem constraints are that each box is mislabeled.

Next, you would want to search for and retrieve from your memory problems similar to the one you are attempting to solve.

Here, that would be the Apples and Oranges analogy you just read through.

Then, you would want to compare the objects and constraints in your current problem and the problem you retrieved. This allows you to determine how similar the problems are, and we see that these two problems are quite similar.

[put up correspondence B]

As you can see, the problems have different objects (fruit versus gambling chips), but similar problem goals (determine which box contained which type of fruit/chip), and constraints (each box was mislabeled). So, the apples and oranges analogy and the casino problem are isomorphic to each other and it would be appropriate to use the apples and oranges as an analogy when solving the Casino problem.

After comparing the problems, you would apply the analogous solution or strategy to your current problem and evaluate it for its appropriateness.

Now, let's try to solve the casino problem.

[give five minutes to solve this problem unless everyone finishes sooner]

Okay, let's see how your solution compares to the correct solution strategy to the Casino problem.

[put up Casino solution and read out loud]

So, you may have noticed when solving the Casino problem that the Apples and Oranges problem was an appropriate analogy to the Casino problem. Did you find this to be a useful analogy with which to solve the Casino problem?

Go ahead and correct your solution strategy using the same paper.

Okay, let's practice some more with analogy set number two.

[hand out set two to each student]

Please read through each problem and solution as I hand these out but do not write on these forms.

[wait until each student has read through all three analogies]

Now, using the analogical problem solving I described for you, let's try to solve the first practice problem.

[hand out three little pigs problem and read out loud]

Again, when solving problems using analogies, the first step is to identify the goal of the current problem you are trying to solve, which again is the information you need to understand to solve the problem. In this case, the goal is to determine how to get the three little pigs house on top of the very steep hill.

Next, you identify the problem's objects--here the objects are the house, a hill, and three little pigs.

Then you identify the problem constraints--the constraint in this problem is that the pigs are not strong enough to move their house on top of the hill.

Next, you would want to search for and retrieve from your memory problems similar to the one you are attempting to solve. Here, that would be the ants analogy you just read through.

Then, you would want to compare the objects and constraints in your current problem and the problem you retrieved. This allows you to determine how similar the problems are, and we see that these two problems are quite similar. Let's take a look at how we might compare these two problems.

[put up correspondence C]

As you can see, the problems have different objects (food versus a house, ants versus pigs), but similar problem goals (determine how to get heavy objects on top of steep hills), and constraints (the ants and pigs are not strong enough to move the objects on their own). So, the ants analogy and the three little pigs problem are isomorphic to each other and it would be appropriate to use the ants as an analogy when solving the pigs problem.

After comparing the problems, you would apply the analogus solution or strategy to your current problem and evaluate it for its appropriateness.

Now, let's try to solve the three little pigs problem.

[give five minutes to solve this problem unless everyone finishes sooner]

Okay, let's see how your solution compares to the correct solution strategy to the three little pigs problem.

[put up three little pigs solution and read out loud]

So, you may have noticed when solving the three little pigs problem that the ants analogy was an appropriate analogy to the pigs problem.

Did you find this to be a useful analogy with which to solve the pigs problem?

Go ahead and correct your solution strategy using the same paper

One final point is that analogies come by recalling previously seen problems and they are not necessarily always given to us at the time of problem solving.

So the first best step, after identifying the problems' goal, is to ask yourself "have I ever seen a problem like this before?" and retrieve the relevant information from memory.

You all did a really good job at following the analogical problem solving process.

First, you determined the problems' goal, identified any similarities and differences between two problems, you attempted to apply the analogical strategy and solution to the problem you were solving, you modified the solution if necessary, and, finally, you correctly solved the problems.

III. Conclusion

That concludes the first day of our problem-solving study. I want to thank each of you for participating. As I said before, I have a piece of paper for each of you that lists the day, date, time, and room of your next session.

Remember, it is extremely important that each of you participate in the remaining sessions, so please look over these days and times to make sure you can attend.

As you have been told, you will receive extra credit points when you complete the study, so not only are you helping us out--you receive something in return!

And, as I have told you, you may win one of four $25.00 gift certificates for completing the study, and you may win up to four chances to win the $200.00 grand prize depending on the number of qualifying problems you solve correctly during session three and the final testing session.

One final note, during the next few weeks it is vital that you do not discuss this training, the testing you will complete, or your chance to win the grand prize of $200.00 with anyone in this group or anyone else in your Psychology class.

Again, thank you for coming.

If there any no more questions you are free to go after you have picked up your paper and have made sure that your name is written on the back of each paper I handed out to you.

[collect all handouts at this time and let them leave only after you have given them their individual confirmation slips]

Teacher-Generated Extended Training Protocol

Day Two

[begin this session by taking roll call!!]

I. Introduction and Review

I would like to welcome you all back to day two of training.

Let's begin with a recap of what we learned from day 1 training.

When solving problems using the analogical problem solving method, the first step is to identify the goal of the current problem you are trying to solve, which again is the information you need to understand to solve the problem.

Next, you would want to search for and retrieve from your memory problems similar to the one you are attempting to solve.

Then, you would want to compare the objects and constraints in your current problem and the problem you retrieved. This allows you to determine how similar the problems are.

After comparing the problems, you would want to retrieve the solution or strategy used in the similar problem, your analogy, and finally you would apply this solution or strategy to your current problem and evaluate it for its appropriateness.

Before we begin, let me remind you that as an added bonus for your participation in this entire study, you will have the opportunity to win up to $225.00 in cash and prizes.

First, as I have told you, you may win one of four $25.00 gift certificates just for completing this study.

Second, depending on your performance during the third training session and final testing session you have the chance to earn up to four chances for a grand prize of $200.00. For each qualifying problem that you solve correctly on the third day of training and during the testing session you will earn one chance to win $200.00.

As an example, if you solve one of the two problems correctly on day three and two problems during the testing session, you will have three chances to win the grand prize.

What will be important for you to remember is that I will be teaching you things during this training session that you will need to remember to be able to correctly solve problems during sessions three and four. So, the more you pay attention and learn, the more chances you will have to win.

Today, we will learn how to use analogies that do not contain the complete information about solving a problem.

A complete analogy is one that provides you with the initial and final goal states, objects and constraints, strategies, and a solution. All of the analogies we used during the last training session would fall into this category.

A partial analogy will provide you with almost all the information that a complete analogy will, but it is usually missing the problem's solution strategy.

To determine how we might use partial analogies, let's begin by having you solve a practice problem.

[hand out cord problem and read out loud]

Again, first, you determine the problems' goal, objects, and constraints, and then search for and retrieve from your memory problems similar to the one you are attempting to solve.

Next, you would want to compare the objects and constraints in your current problem and the problem you retrieved, and if you determine the two problems are similar enough, apply the solution or strategy used in the analogous problem to your current problem and evaluate it for its appropriateness.

Although I have not presented you with the analogy to the cord problem during today's session thus far, I did present you with the analogy during session one. The analogy to the cord problem is the birthday problem. Let's see how these two problems compare.

[put up correspondence D]

Here, we find that these two problems have similar objects (ribbons and cords), goals (tie the two ribbons/cords together), and constraints (you cannot reach one ribbon/cord while holding the other one). Thus, the birthday problem appears to be an appropriate analogy to use to solve the cord problem. You should have noticed that this pair of problems and how you will solve this problem is different from the situations we presented you with on day one of training. Here, you do not have a solution that you can apply to the target problem.

Okay, go ahead and solve this problem.

[give five minutes to solve unless everyone finishes sooner]

Let's see how your solution compares to the correct solution for the cord problem.

[put up solution and read out loud]

Even though the birthday problem did not provide a solution strategy, by trying to solve the birthday problem first, you can take the generated solution strategy and apply it to the cord problem.

II. Practice

Let's continue working with partial analogies with this first set of three analogies.

[hand out set one to each student]

Please read through each problem and solution as I hand these out but do not write on these forms.

[wait until each student has read through all three analogies]

Now, using the analogical problem solving I described for you, let's try to solve the first practice problem.

[hand out jungle problem and read out loud]

Remember, when solving problems using analogies, the first step is to identify the goal of the current problem you are trying to solve, which again is the information you need to understand to solve the problem. In this case, the goal is to determine how the man will be able to tie two vines together.

Next, you would identify the objects of the problem--here the objects are vines.

Then you identify the constraints of the problem--the constraint in the jungle problem is that the person is unable to reach one vine while holding the other vine.

Next, you would want to search for and retrieve from your memory problems similar to the one you are attempting to solve.

[put up correspondence E]

Here, that would be the inaugural gala analogy you just read through because although the problems have different objects (ribbons versus vines), they have similar problem goals (determine how to tie the two ribbons/vines together), and constraints (the person is unable to reach one ribbon/vine while holding the other ribbon/vine). So, the inaugural gala analogy and the jungle problem are completely similar to each other and it would be appropriate to use the inaugural gala as an analogy when solving the jungle problem.

After comparing the problems, you would apply the solution or strategy used in the analogy to your current problem and evaluate it for its appropriateness.

Now, let's try to solve the jungle problem.

[give five minutes to solve this problem unless everyone finishes sooner]

Okay, let's see how your solution compares to the correct solution strategy to the jungle problem.

[put up jungle solution and read out loud]

So, you may have noticed when solving the jungle problem that the inaugural gala problem was an appropriate, although partial, analogy to the jungle problem.

Did you find this to be a useful analogy with which to solve the jungle problem? Were you able to generate a solution strategy for the inaugural gala and then apply that strategy to the jungle problem?

Okay, let's practice some more with analogy set number two.

[hand out set two to each student]

Please read through each problem and solution as I hand these out but do not write on these forms.

[wait until each student has read through all three analogies]

Now, using the analogical problem solving I described for you, let's try to solve the first practice problem.

[hand out Trump Suit problem and read out loud]

Again, when solving problems using analogies, the first step is to identify the goal of the current problem you are trying to solve, which again is the information you need to understand to solve the problem. In this case, the goal is to determine how to get the caviar, boat, and investor to Mr. Trump's yacht.

Next, you would identify the objects of the problem--here, the objects are caviar, boat, and an investor.

Then you identify the problem constraints--here, the constraint is that the water is too shallow for safe passage.

Next, you would want to search for and retrieve from your memory problems similar to the one you are attempting to solve.

[put up correspondence F]

Here, that would be the Wine Merchants problem you just read through because although the problems have different objects (wine, horse, cart, and merchant versus caviar, boat, and investor), they have similar problem goals (determine how to get the merchandise to the King/Mr. Trump), and constraints (the water is too fast/shallow for safe passage). So, the Trump Suit and the Wine Merchants problems are isomorphic to each other and it would be appropriate to use the Wine Merchants as an analogy when solving the Trump Suit problem.

After comparing the problems, you would want to retrieve the solution or strategy used in the similar problem, your analogy, and finally you would apply this solution or strategy to your current problem and evaluate it for its appropriateness.

Now, let's try to solve the Trump Suit problem.

[give five minutes to solve this problem unless everyone finishes sooner]

Okay, let's see how your solution compares to the correct solution strategy to the Trump Suit problem.

[put up Trump solution and read out loud]

So, you may have noticed when solving the Trump Suit problem that the Wine Merchants problem was an appropriate isomorphic, although partial, analogy to the Trump Suit problem. By generating a correct solution strategy to the Wine Merchants problem, you will find that it becomes a useful analogy with which to solve the Trump Suit problem.

In comparison to the previous practice problem and its analogy, it was a little more difficult this time to generate a correct solution strategy for the Trump Suit problem because there could be several possible correct solution strategies for the Wine Merchants problem.

Using a partial analogy may not always lead to a correct solution strategy for the target problem, but it can provide a solid starting point and may in fact lead you to a correct solution strategy.

One final point is that analogies come by recalling previously seen problems and they are not necessarily always given to us at the time of problem solving.

So the first best step, after identifying the problems' goal, is to ask yourself "have I ever seen a problem like this before?" and retrieve the relevant information from memory.

You all did a really good job at following the analogical problem solving process.

First, you determined the problems' goal, identified any similarities and differences between two problems, you attempted to apply the analogical strategy and solution to the problem you were solving, you modified the solution if necessary, and, finally, you correctly solved the problems.

III. Conclusion

That concludes the second day of our problem-solving study. I want to thank each of you for participating. As I said before, I have a piece of paper for each of you that lists the day, date, time, and room of your next session.

Remember, it is extremely important that each of you participate in the remaining sessions, so please look over these days and times to make sure you can attend.

As you have been told, you will receive extra credit points when you complete the study, so not only are you helping us out--you receive something in return!

And, as I have told you, you may win one of four $25.00 gift certificates for completing the study, and you may win up to four chances to win the $200.00 grand prize depending on the number of qualifying problems you solve correctly during session three and the final testing session.

One final note, during the next few weeks it is vital that you do not discuss this training, the testing you will complete, or your chance to win the grand prize of $200.00 with anyone in this group or anyone else in your Psychology class.

Again, thank you for coming.

If there any no more questions you are free to go after you have picked up your paper and have made sure that your name is written on the back of each paper I handed out to you.

[collect all handouts at this time and let them leave only after you have given them their individual confirmation slips]

Teacher-Generated Extended Training Protocol

Day Three

[begin this session by taking roll call!!]

I. Introduction and Review

I would like to welcome you all back to day three of training.

Let's begin with a recap of what we learned from day 2 training.

When solving problems using the analogical problem solving method, the first step is to identify the goal of the current problem you are trying to solve, which again is the information you need to understand to solve the problem.

Next, you would want to search for and retrieve from your memory problems similar to the one you are attempting to solve.

Then, you would want to compare the objects and constraints in your current problem and the problem you retrieved. This allows you to determine how similar the problems are.

After comparing the problems, you would want to retrieve the solution or strategy used in the similar problem, your analogy, and finally you would apply this solution or strategy to your current problem and evaluate it for its appropriateness.

On day one, you also learned how to use complete analogies in solving new problems.

Remember, complete analogies are those which provide the initial and final goal states, objects and constraints, strategies, and a solution strategy, whereas a partial analogy is usually missing the solution strategy but provides all the other elements.

On day two, you also learned how to use partial analogies when solving new problems.

Here, the process is a little different from using complete analogies because you actually need to try to generate a correct solution strategy for the partial analogy and then apply this strategy to the new problem.

Before we begin, let me remind you that as an added bonus for your participation in this entire study, you will have the opportunity to win up to $225.00 in cash and prizes.

First, as I have told you, you may win one of four $25.00 gift certificates just for completing this study.

Second, depending on your performance during this training session and the final testing session you have the chance to earn up to four chances for a grand prize of $200.00. For each special problem that you solve correctly during today's session and during the testing session you will earn one chance to win $200.00.

II. Practice

Let's begin with this set of analogies and practice problem.

[hand out set one to each student]

Please read through each problem and solution as I hand these out but do not write on these forms.

[wait until each student has read through all three analogies]

Now, using the analogical problem solving method I described for you, let's try to solve the practice problem.

[hand out marching band problem and read out loud]

Again, when solving problems using analogies, the first step is to identify the goal of the current problem you are trying to solve, which again is the information you need to understand to solve the problem.

In this case, the goal is to determine how many students there were in the High School Band.

Next, you identify the objects of the problem--here, the objects are a boy and band members.

Then you identify the constraints of the problem--the constraints are that you need an equal number of band members in each row.

Next, you would want to search for and retrieve from your memory problems similar to the one you are attempting to solve. Here, that would be the Renshaw problem.

Then, you would want to compare the objects and constraints in your current problem and the problem you retrieved. Let's take a look at how we might compare these two problems.

[put up correspondence G]

As you can see, the problems have different objects (man and wife and vegetables vs boy and band members), but similar problem goals (determine how many total vegetables to buy and the total number of band members), and constraints (need an equal number of vegetables and an equal number of band members in each row). So, the Renshaw analogy and the marching band problem are similar to each other and it would be appropriate to use the Renshaw as an analogy when solving the marching band problem.

Remember, after comparing the problems, you would want to retrieve the solution or strategy used in the similar problem, your analogy, and finally you would apply this solution or strategy to your current problem and evaluate it for its appropriateness.

Now, let's try to solve the marching band problem.

[give five minutes to solve this problem unless everyone finishes sooner]

Okay, let's see how your solution compares to the correct solution to the marching band problem.

[put up marching band solution and read out loud]

Let's continue by having you solve this first practice problem.

[hand out traveler liar/truth teller problem and read out loud]

Again, first, you determine the problems' goal, objects, and constraints, and then search for and retrieve from your memory problems similar to the one you are attempting to solve.

Next, you would want to compare the objects and constraints in your current problem and the problem you retrieved, and if you determine the two problems are

similar enough, apply the solution or strategy used in the analogy to your current problem and evaluate it for its appropriateness
Okay, go ahead and solve this problem.

Remember, you may earn one chance to win the $200.00 prize by correctly solving this problem.

[give five minutes to solve unless everyone finishes sooner]

Let's see how your solution compares to the correct solution for the traveler liar/truth teller problem.

First, switch your paper with the person sitting next to you. I want each of you to score the solution in front of you as either "correct" or "incorrect" and write the word "correct" or "incorrect" in the top right hand corner of the paper.

[put up solution and read out loud]

You may have remembered an analogy from your first day of training that may have helped you solve the traveler problem--the quiz game analogy. You may have found it helpful to apply the quiz game solution strategy to the traveler problem. If you had done so, you would have generated a correct solution strategy to the traveler problem.

Okay, here is the other problem with which you may earn a chance to win the $200.00 prize.

[hand out king and poison cups problem and read out loud]

Again, first, you determine the problems' goal, objects, and constraints, and then search for and retrieve from your memory problems similar to the one you are attempting to solve.

Next, you would want to compare the objects and constraints in your current problem and the problem you retrieved, and if you determine the two problems are similar enough, apply the solution or strategy used in the analogy to your current problem and evaluate it for its appropriateness.

Okay, go ahead and solve this problem.

[give five minutes to solve unless everyone finishes sooner]

Let's see how your solution compares to the correct solution for the king and poison cups problem

First, switch your paper with the person sitting next to you. I want each of you to score the solution in front of you as either "correct" or "incorrect" and write the word "correct" or "incorrect" in the top right hand corner of the paper.

[put up solution and read out loud]

Again, you may have remembered an analogy from your second day of training that may have helped you solve the poison cups problem--the street vendor analogy.

Even though the street vendor problem did not provide a solution strategy, could you have used it to solve the poison cups problem? Yes, by trying to solve the street vendor problem first, you can take the generated solution strategy and apply it to the poison cups problem.

You may have found it helpful to apply the street vendor solution strategy to the poison cups problem. If you had done so, you would have generated a correct solution strategy to the poison cups problem.

You all did a really good job at following the analogical problem solving process.

First, you determined the problems' goal, identified any similarities and differences between two problems, you attempted to apply the analogical strategy and solution to the problem you were solving, you modified the solution if necessary, and, finally, you correctly solved the problems.

III. Conclusion

That concludes the third day of our problem-solving study. I want to thank each of you for participating. As I said before, I have a piece of paper for each of you that lists the day, date, time, and room of your fourth and final session.

Remember, it is extremely important that each of you participate in the final session, so please look over these days and times to make sure you can attend.

As you have been told, you will receive extra credit points when you complete the study, so not only are you helping us out--you receive something in return!

And, as I have told you, you may win one of four $25.00 gift certificates for completing the study. In addition, you will have two more chances at winning the $200.00 grand prize by solving two problems at the next session.

One final note, during the next few weeks it is vital that you do not discuss this training, the testing you will complete, or your chance to win the grand prize of $200.00 with anyone in this group or anyone else in your Psychology class.

Again, thank you for coming.

If there any no more questions you are free to go after you have picked up your paper and have made sure that your name is written on the back of each paper I handed out to you.

[collect all handouts at this time and let them leave only after you have given them their individual confirmation slips]

Appendix G.

Learner-Generated Condensed Training Protocol

[Begin this training session by taking roll call!!]

I. Introduction

Hello and thank you for agreeing to participate in our problem-solving study. My name is ________________ and I will be your trainer today. Let me begin first by telling you a little about myself. I am in the Psychology program here at Utah State University, and am currently in my ______ year of the program.

Dune Ives, the project coordinator asked me to give you a few pointers on how to become better problem solvers.

As you have been told, this training is the third day of our four-part study. The fourth part will consist of testing your problem solving ability in a separate section for which you should have already signed up.

I have a piece of paper for each of you that lists the day, date, time, and room of your fourth and final session that I will hand out to you at the end of our session today.

First, let me give you a brief overview of what I will be covering today. As I said before, I will teach you about specific types of problems and problem solving strategies, and then I will put your knowledge to the test and let you practice what I have taught you.

As an added bonus for your participation in this entire study, you will have the opportunity to win up to $300.00 in cash and prizes.

First, as Dune has told you, you may win one of four $25.00 gift certificates just for completing this study.

Second, depending on your performance during this training session and the final testing session you will earn up to four chances for a grand prize of $200.00. For each qualifying problem that you solve correctly today and during the testing session you will earn one chance to win $200.00.

As an example, if you solve one of the two problems correctly today and two problems during the testing session, you will have three chances to win the grand prize. The last two problems I have you solve today will be the problems with which you may win chances if you solve them correctly.

What will be important to remember is that I will be teaching you things during this training session that you will need to remember to be able to correctly solve problems today and during the final testing session. So, the more you pay attention and learn, the more chances you will have to win.

Are there any questions before we get started?

[allow only a couple of minutes for questions and answers]

Great, let's get started.

II. Problem Solving Strategies

There are several ways to solve problems.

The first method is called **trial and error**.

In this method, you attempt to solve the problem using one method, evaluate your efforts, and either solve the problem, try a new method, or stop trying because you have run out of methods.

Let's work through an example that can be solved through trial and error.

[put Tower of Hanoi 3-disk problem up on the overhead and read it out loud]

First, you might suggest moving disk A to peg two, then disk B to peg two. Upon evaluation of this solution, you discover that this is impossible since you cannot move a larger disk on top of a smaller disk.

Okay, so let's try moving disk B to peg three and disk C to peg two. Again, this solution also will not work.

So that is how trial and error works. You find one approach, try it, and when it no longer works go on to the next approach or stop trying because you have exhausted your methods.

Let's take a look at the correct solution strategy for the Tower of Hanoi 3-disk problem.

[put up Tower of Hanoi 3-disk problem solution strategy and read out loud]

Another problem that you could use the trial and error method with is the parade problem.

[put up parade problem on the overhead and read it out loud--make sure students do not generate any solutions and shout them out]

First, you might suggest that the general put the parade on television. Upon evaluation of this solution, you discover that this is impossible since the fortress was surrounded by farms and villages and the chances of them having tv's is very slim.

Okay, so now you might suggest having the army walk on very high stilts in the parade so that everyone could see them above the trees, but upon evaluation of this solution you find that this may not be the best solution.

Again, that is how trial and error works. You find one approach, try it, and when it no longer works go on to the next approach or stop trying because you have exhausted your methods.

A second problem solving strategy is called **working backwards**, in which you identify your goal state, that is, what the problem will look like when it is solved. You continue to work backward from this state until you have reached the beginning.

Here is an example of a problem that might require using working backwards.

[put poker problem up on the overhead and read it out loud--make sure students do not generate any solutions and shout them out]

In this problem, you should first identify what the goal is--to find out what the original stake of each player was and begin to work backwards from the last game--game number three and continue until you have figured out what happened in the second and first games.

Another strategy is called **working forward** in which you either break the problem into smaller sub-goals and provide a means of solving each sub-goal, or you identify the initial state of the problem (what information you have) and its final goal state (what the problem should end up looking like) and work to decrease the difference between the two.

Again, let's look at an example of a problem in which you might use working forward.

[put general problem up on the overhead and read it out loud]

Here, we know that the general must attack the fortress with his entire army and that only small bodies of men could pass over the planted mines safely. Thus, we have identified the initial state of the problem. We also know that the final goal is to determine what the general must do to capture the fortress without detonating the mines, and, as a result, blowing up the road and destroying many neighboring villages.

Next, we would begin to decrease the differences between where the general is and where he must go with his army. Or, we could break up the problem into subgoals--the first being sending his men over the mines safely and the second being attacking the fortress--and begin by solving each subgoal.

A second problem you could use the working forward method with is Renshaw problem.

[put up the Renshaw problem on the overhead and read it out loud]

Here, we know that the Renshaw's have determined that they will buy six of each kind of vegetable to plant in their garden--thus, we have identified the initial state of the problem. We also know that the final goal state is to determine what would be the fewest total number of plants the Renshaws could buy that would fill each row of their garden evenly if they were to buy six of each kind of vegetable.

From here, we would work to decrease the difference between what the Renshaws have decided on and what they still need to know about the fewest total number of plants to buy.

Let's see how the correct solution strategy is developed when we use the working forward method.

[put up Renshaw solution on overhead and read out loud]

A third problem you could use the working forward method with is the fireman problem.

[put up fireman problem on the overhead and read it out loud--make sure students do not generate any solutions and shout them out]

Here, we know that the fireman must put out the fire with a large amount of water. Thus, we have identified the initial state of the problem. We also know that the final goal is to determine how best to throw a large amount of water onto the fire using only a limited amount of buckets.

Next, we would decrease the difference between the fireman's present situation and what he must do to put out the fire. Or, we could break up the problem into subgoals--the first being organizing his men to use a small number of buckets and the second being putting out the fire--and begin by solving each subgoal.

Finally, one of the most effective strategies is problem solving by **analogy**.

In this case, you would search for solutions to problems similar (that is, analogous) to the one you are presented with, and test whether this solution would be appropriate for the present problem.

Let's discover what steps you should consider when solving by analogy by using the Tower of Hanoi 4-disk problem.

[hand out problem and read it out loud]

Using the paper labeled "Tower of Hanoi," I want you to consider what steps you might engage in if I asked you to solve this problem. I do not want you to try to solve this problem, rather, I want you to focus on the analogical problem solving process instead of the solution generation process. For example, what might be the first problem solving stage you would go through, the second, and so on.

[give them three minutes to complete this task]

Okay, let's look at the steps you listed. What would be the first thing you would do? the second? the third? etc.

[elicit response from each student and write on blank overhead--responses should fall into these categories--determine goal, objects, and constraints of the target problem, search for and retrieve an analogous problem, apply solution strategy from analogous problem, evaluate appropriateness of analogous solution strategy]

Have you ever encountered a problem similar to the Tower of Hanoi 4-disk problem?

[elicit response from each student--should identify Tower of Hanoi 3-disk problem]

Right, the Tower of Hanoi 3-disk problem.

Now, recall what you remember from that problem and on the same paper I want you to write down anything you notice about this problem in comparison to the Tower of Hanoi 3-disk problem.
[give students three minutes to complete this task]

Great, let's have everyone tell the whole group one thing that they noticed about these problems.

[elicit responses from each student and write responses on a blank overhead--possible prompts, if needed--what similarities did you notice between these problems' goal states? How about the objects they used in the problems? Did you notice any similarities between constraints in the problems? How about the amount of information each problem provided you with--any differences or similarities?]

How could you make use of the information found in the Tower of Hanoi 3-disk problem?

[elicit responses from each student]

Normally, you would solve new problems by using analogies you have been exposed to before, but for right now I will provide you with an analogy for each problem to be solved.

For the remaining problems you will be given, I want you to practice problem solving using the analogical method.

II. Practice

Okay, it looks like you are getting the hang of this, let's try this again with another pair of problems--the book burners and book lovers problem and the missionaries and cannibals problems.

[hand out each problem to student]

Take just a minute to read through both problems. Okay, on the paper labeled "book burners," I want you to write down anything you notice about the book burner problem in comparison to the cannibal problem.

[give students 2 minutes to complete this task]

Great, let's have everyone tell the whole group one thing that they noticed about these problems.

[elicit responses from each student and write responses on a blank overhead--possible prompts, if needed--what similarities did you notice between these problems' goal states? How about the objects they used in the problems? Did you notice any similarities between constraints in the problems? How about the amount of information each problem provided you with--any differences or similarities?]

How could you make use of the information found in the cannibal problem?

[elicit responses]

Now, take another few minutes to solve the book burner problem. You may want to refer back to the problem-solving stages you listed on the Tower of Hanoi paper.

[give 5 minutes to solve the problem]

How did everyone do?

[elicit response from everyone]

How do your answers compare to the correct solution to the book burner problem?

[put up correct solution on overhead and read out loud]

Go ahead and correct your solution strategy using the same paper.

Let's try this again with another problem--the hobbits and orcs.

[hand out problem to each student]

Okay, on the paper labeled "hobbits and orcs," I want you to write down anything you notice about this problem in comparison to the book burner and cannibal problems.

[give students 3 minutes to complete this task]

Great, let's have everyone tell the whole group one thing that they noticed about these problems.

[elicit responses from each student and write responses on a blank overhead--possible prompts, if needed--what similarities did you notice between these problems' goal states? How about the objects they used in the problems? Did you

notice any similarities between constraints in the problems? How about the amount of information each problem provided you with--any differences or similarities?]

Now, take a look at the fourth problem--the men and boys problem.

[hand out analogy and read out loud]

Using the same process as before, and using the "hobbits and orcs" paper again, write down anything you notice about the men and boys problem in comparison to the hobbits and orcs problem.

[give students 3 minutes to complete this task]

Great, let's have everyone tell the whole group one thing that they noticed about these problems.

[elicit responses from each student and write responses on a blank overhead--possible prompts, if needed--what similarities did you notice between these problems' goal states? How about the objects they used in the problems? Did you notice any similarities between constraints in the problems? How about the amount of information each problem provided you with--any differences or similarities?]

How could you make use of the information found in the hobbits and orcs problem?

[elicit responses]

Was there anything different about this pair of analogies and the previous pair?

[elicit responses from students--should say these two problems are similar but not the same and the previous pair were the same]

That is right, these two problems are only somewhat similar to each other while the previous pair were completely similar. Using the same piece of paper, take another few minutes to solve the men and boys problem. Again, you may want to refer back to the problem-solving steps you developed on the Tower of Hanoi paper.

[give 5 minutes to solve the problem]

Did the hobbits and orcs solution strategy help you solve the men and boys problem?

[elicit responses]

Even though the hobbits and orcs problem may be only partially isomorphic, its solution strategy can be useful when attempting to solve the men and boys problem.

How do your answers compare to the correct solution to the men and boys problem?

[put up correct solution on overhead and read out loud]

Go ahead and correct your solution strategy using the same paper.

Now let's try to solve two additional problems.

The first problem is the Trump suit problem and its corresponding analogy--the wine merchants problem.

[hand out Trump problem and Wine Merchants analogy and read through both problems out loud]

The Trump Suit problem is the first problem with which you may earn a chance at winning the $200.00 prize if you solve it correctly.

Using the same process as before, and using the "Trump suit" paper, write down anything you notice about the Trump Suit problem in comparison to the Wine Merchants problem.

[give students 3 minutes to complete this task]

Great, let's have everyone tell the whole group one thing that they noticed about these problems.

[elicit responses from each student and write responses on a blank overhead--possible prompts, if needed--what similarities did you notice between these problems' goal states? How about the objects they used in the problems? Did you notice any similarities between constraints in the problems? How about the amount of information each problem provided you with--any differences or similarities?]

How does this pair of problems compare to the previous pair of problems you have been presented with?

[elicit responses from each student--should indicate that previous pair provided solution whereas with this pair the Wine Merchant problem did not]

That is right, we call analogies that provide us with all the needed information including solutions complete analogies, and we call analogies that provide us with everything but the solution partial analogies.

Now, take a minute to solve the Trump suit problem using the piece of paper labeled "Trump suit."

[give 5 minutes to solve the problem]

How did everyone do?

[elicit response from everyone]

Okay, switch papers with the person sitting next to you.

I am going to put up the correct solution strategy and I want you to correct the paper in front of you as either correct or incorrect by writing "correct" or "incorrect" in the top right hand corner of the paper.

[put up correct solution on overhead and read out loud]

Great, you are all getting the idea.

Let me ask you a question about this process--what do you think you did that follows good analogical problem solving?

[have each student respond]

What do you think that maybe didn't follow good analogical problem solving?

[have each student respond]

Now, was the Wine Merchant problem useful to you in solving the Trump Suit problem? Why? Why not? What would have made it more useful?

[have each student respond]

The last problem to be solved is the marching band problem.

[hand out the marching band problem and read out loud]

The marching band problem is the second problem with which you may earn a chance at winning the $200.00 prize if you solve it correctly.

Do you recall a problem that you have been presented with earlier that would serve as an appropriate analogy to you if you were to solve the marching band problem?

That's right, the Renshaw problem.

Using the problem solving stages you have generated, try to solve the marching band problem. Write your solution on the piece of paper labeled "marching band."

[give students 5 minutes to complete this exercise]

Now let's see how each of you did.

[first, go around room asking about how they solved the problem--what was their first stage, last stage--and then go back around the room and elicit their solutions to the problem]

Now, compare your solution to the actual solution.

Okay, switch papers with the person sitting next to you. I am going to put up the correct solution strategy and I want you to correct the paper in front of you as either correct or incorrect by writing "correct" or "incorrect" in the top right hand corner of the paper.

[put up marching band solution on the overhead and read out loud]

Great, you are all getting the idea.

You all did a really good job at following the analogical problem solving process.

Now, let's write the steps on the board that you should take when solving a problem by the analogical problem solving method. You tell me what would be the first step....the second step.... third step.... fourth step.... and the final step.....

[put all this information on the board or blank overhead and the students should arrive at: First, you determine the problems' goal, identify any similarities and differences between two problems, you attempt to apply the analogical solution

strategy to the problem you are solving, you modify the solution if necessary, and, finally, you correctly solve the problem.]

One final point is that analogies come by recalling previously seen problems and they are not necessarily always given to us at the time of problem solving as you just saw.

So the first best step, after identifying the problem's goal, is to ask yourself "have I ever seen a problem like this before?" and retrieve the relevant information from memory.

III. Conclusion

That concludes the third part of our problem-solving study. I want to thank each of you for participating. As I said before, I have a piece of paper for each of you that lists the date, day, time, and room of the fourth and final testing session.

Remember, it is extremely important that each of you participate in the fourth part, so please look over these days and times to make sure you can attend.

As you have been told, you will receive extra credit points when you complete the study, so not only are you helping us out--you receive something in return!

And, as I told you earlier, you may win up to $225.00 in cash and prizes for completing the study and for solving problems correctly.

Today, I gave you two chances to win the $200.00 cash prize, and during the final testing session you will have two more chances to win.

One final note, during the next few weeks it is vital that you do not discuss this training, the testing you will complete, or your chance to win the grand prize of $200.00 with anyone in this group or anyone else in your Psychology class.

Again, thank you for coming.

If there any no more questions you are free to go after you have picked up your paper and have made sure that your name is written on the back of each paper I handed out to you.

[collect all handouts at this time and let them leave only after they have confirmed their testing date and time with you and you have given them their individual confirmation slips]

Appendix H.

Learner-Generated Extended Training Protocol

Day One

[Begin this training session by taking roll call!!]

I. Introduction

Hello and thank you for agreeing to participate in our problem-solving study. My name is ________________ and I will be your trainer today. Let me begin first by telling you a little about myself. I am in the Psychology program here at Utah State University, and am currently in my ______ year of the program.

Dune Ives, the project coordinator asked me to give you a few pointers on how to become better problem solvers.

As you have been told, this training is the first day of our four-part study. The second and third days will consist of similar training, while the fourth part will consist of testing your problem solving ability in a separate section for which you should have already signed up.

I have a piece of paper for each of you that lists the day, date, time, and room of your next session that I will hand out at the end of our session today.

First, let me give you a brief overview of what I will be covering today. As I said before, I will teach you about specific types of problems and problem solving strategies, and then I will put your knowledge to the test and let you practice what I have taught you.

As an added bonus for your participation in this entire study, you will have the opportunity to win up to $225.00 in cash and prizes.

First, as Dune has told you, you may win one of four $25.00 gift certificates just for completing this study.

Second, depending on your performance during the third training session and final testing session you have the chance to earn up to four chances for a grand prize of $200.00. For each qualifying problem that you solve correctly on the third day of training and during the testing session you will earn one chance to win $200.00.

As an example, if you solve one of the two problems correctly on day three and two problems during the testing session, you will have three chances to win the grand prize.

What will be important for you to remember is that I will be teaching you things during this training session and your second training session that you will need to remember to be able to correctly solve problems during sessions three and four. So, the more you pay attention and learn, the more chances you will have to win.

Are there any questions before we get started?

[allow only a couple of minutes for questions and answers]

Great, let's get started.

II. Problem Solving Strategies

There are several ways to solve problems.

The first method is called **trial and error**.

In this method, you attempt to solve the problem using one method, evaluate your efforts, and either solve the problem, try a new method, or stop trying because you have run out of methods.

Let's work through an example that can be solved through trial and error.

[put Tower of Hanoi 3-disk problem up on the overhead and read it out loud]

First, you might suggest moving disk A to peg two, then disk B to peg two. Upon evaluation of this solution, you discover that this is impossible since you cannot move a larger disk on top of a smaller disk.

Okay, so let's try moving disk B to peg three and disk C to peg two. Again, this solution also will not work.

So that is how trial and error works. You find one approach, try it, and when it no longer works go on to the next approach or stop trying because you have exhausted your methods.

Let's take a look at the correct solution strategy for the Tower of Hanoi 3-

disk problem.

[put up Tower of Hanoi 3-disk problem solution strategy and read out loud]

A second problem solving strategy is called **working backwards**, in which you identify your goal state, that is, what the problem will look like when it is solved. You continue to work backward from this state until you have reached the beginning.

Here is an example of a problem that might require using working backwards.

[put poker problem up on the overhead and read it out loud]

In this problem, you should first identify what the goal is--to find out what the original stake of each player was and begin to work backwards from the last game--game number three and continue until you have figured out what happened in the second and first games.

Another strategy is called **working forward** in which you either break the problem into smaller sub-goals and provide a means of solving each sub-goal, or you identify the initial state of the problem (what information you have) and its final goal state (what the problem should end up looking like) and work to decrease the difference between the two.

Again, let's look at an example of a problem in which you might use working forward.

[put three little pigs problem up on the overhead and read it out loud]

Here, we know that the three little pigs need to move their house to escape the terror of the big bad wolf. Thus, we have identified the initial state of the problem. We also know that the final goal is to determine how the three little pigs, who are not strong enough to move their house on top of the big hill, will be able to move their house.

Next, we would begin to decrease the differences between where the house is now and where the house must go to. Or, we could break up the problem into subgoals--the first being escaping the wrath of the big bad wolf and the second being moving the house on top of the big hill--and begin by solving each subgoal.

Finally, one of the most effective strategies is problem solving by **analogy**.

In this case, you would search for solutions to problems similar (that is, analogous) to the one you are presented with, and test whether this solution would be appropriate for the present problem. Let's discover what steps you should consider when solving by analogy by using the Tower of Hanoi 4-disk problem.

[hand out problem and read it out loud]

Using the paper labeled "Tower of Hanoi," I want you to consider what steps you might engage in if I asked you to solve this problem.

I do not want you to try to solve this problem, rather, I want you to focus on the analogical problem solving process instead of the solution generation process. For example, what might be the first problem solving stage you would go through, the second, and so on.

[give them three minutes to complete this task]

Okay, let's look at the steps you listed. What would be the first thing you would do? the second? the third? etc.

[elicit response from each student and write on blank overhead--responses should fall into these categories--determine goal, objects, and constraints of the target problem, search for and retrieve an analogous problem, apply solution strategy from analogous problem, evaluate appropriateness of analogous solution strategy]

Have you ever encountered a problem similar to the Tower of Hanoi 4-disk problem?

[elicit response from each student--should identify Tower of Hanoi 3-disk problem]

Right, the Tower of Hanoi 3-disk problem.

Now, recall what you remember from that problem and on the same paper I want you to write down anything you notice about this problem in comparison to the Tower of Hanoi 3-disk problem.

[give students three minutes to complete this task]

Great, let's have everyone tell the whole group one thing that they noticed about these problems.

[elicit responses from each student and write responses on a blank overhead--

possible prompts, if needed--what similarities did you notice between these problems' goal states? How about the objects they used in the problems? Did you notice any similarities between constraints in the problems? How about the amount of information each problem provided you with--any differences or similarities?]

How could you make use of the information found in the Tower of Hanoi 3-disk problem?

[elicit responses from each student]

Normally, you would solve new problems by using analogies you have been exposed to before, but for right now I will provide you with an analogy for each problem to be solved.

For the remaining problems you will be given, I want you to practice problem solving using the analogical method.

III. Practice

Okay, let's begin with analogy set number one.

[hand out set one to each student]

Please read through each problem and solution as I hand these out but do not write on these forms.

[wait until each student has read through all three analogies]

Okay, on the piece of paper labeled "casino problem" I want you to write down anything you notice about this problem in comparison to the three analogies I just presented to you.

[hand out problem--give students 3 minutes to complete this task]

Great, let's have everyone tell the whole group one thing that they noticed about these problems.

[elicit responses from each student and write responses on a blank overhead--possible prompts, if needed-- did you identify one analogy that was more similar than the others to the casino problem? What similarities did you notice between these problems' goal states? How about the objects they used in the problems? Did you notice any similarities between constraints in the problems? How about

the amount of information each problem provided you with--any differences or similarities?]

Did you identify one problem that would be more appropriate to use as an analogy if I were to ask you to solve the casino problem?

[elicit responses from each student--should state the apples and oranges problem]

Right, the Apples and Oranges problem.

How could you make use of the information found in the Apples and Oranges problem?

[elicit responses from each student]

On the same piece of paper I want you to take another few minutes to solve the casino problem. When solving this problem, you may want to refer back to the problem solving stages you listed on your Tower of Hanoi sheet.

[give 5 minutes to solve the problem]

How did everyone do?

[elicit response from everyone]

How do your answers compare to the correct solution to the casino problem?

[put up correct solution on overhead and read out loud]

Did you find the Apples and Oranges problem to be a useful analogy with which to solve the Casino problem?

[elicit responses from each student]

Go ahead and correct your solution strategy using the same paper.

Okay, let's practice some more with analogy set number two.

[hand out set two to each student]

Please read through each problem and solution as I hand these out but do not write on these forms.

[wait until each student has read through all three analogies]

Okay, on the piece of paper labeled "Three little pigs" I want you to write down anything you notice about this problem in comparison to the three analogies I just presented to you.

[hand out problem--give students 3 minutes to complete this task]

Great, let's have everyone tell the whole group one thing that they noticed about these problems.

[elicit responses from each student and write responses on a blank overhead--possible prompts, if needed-- did you identify one analogy that was more similar than the others to the pigs problem? What similarities did you notice between these problems' goal states? How about the objects they used in the problems? Did you notice any similarities between constraints in the problems? How about the amount of information each problem provided you with--any differences or similarities?]

Did you identify one problem that would be more appropriate to use as an analogy if I were to ask you to solve the pigs problem?

[elicit responses from each student--should state the ants problem]

Right, the ants problem.

How could you make use of the information found in the ants problem?

[elicit responses]

On the same sheet of paper, take another few minutes to solve the pigs problem. Again, you may wish to refer back to the problem solving stages you generated on the Tower of Hanoi paper.

[give 5 minutes to solve the problem]

How did everyone do?

[elicit response from everyone]

How do your answers compare to the correct solution to the pigs problem?

[put up correct solution on overhead and read out loud]

Did you find the ants problem to be a useful analogy with which to solve the pigs problem?

Go ahead and correct your solution strategy using the same paper.

One final point is that analogies come by recalling previously seen problems and they are not necessarily always given to us at the time of problem solving.

So the first best step, after identifying the problems' goal, is to ask yourself "have I ever seen a problem like this before?" and retrieve the relevant information from memory.

You all did a really good job at following the analogical problem solving process.

Now, let's write the steps on the board that you should take when solving a problem by the analogical problem solving method. You tell me what would be the first step....the second step.... third step.... fourth step.... and the final step.....

[put all this information on the board or blank overhead and the students should arrive at: First, you determine the problems' goal, objects, and constraints, search for and retrieve an analogous problem, identify any similarities and differences between two problems, apply the analogical solution strategy to the problem you are solving, you modify the solution if necessary, and, finally, you correctly solve the problem.]

IV. Conclusion

That concludes the first day of our problem-solving study. I want to thank each of you for participating. As I said before, I have a piece of paper for each of you that lists the day, date, time, and room of your next session.

Remember, it is extremely important that each of you participate in the remaining sessions, so please look over these days and times to make sure you can attend.

As you have been told, you will receive extra credit points when you complete the study, so not only are you helping us out--you receive something in return!

And, as I have told you before, you may win one of four $25.00 gift certificates for completing the study, and you may win up to four chances to win the $200.00 grand prize depending on the number of qualifying problems you solve correctly during sessions three and four.

One final note, during the next few weeks it is vital that you do not discuss this training, the testing you will complete, or your chance to win the grand prize of $200.00 with anyone in this group or anyone else in your Psychology class.

Again, thank you for coming.

If there any no more questions you are free to go after you have picked up your paper and have made sure that your name is written on the back of each paper I handed out to you.

[collect all handouts at this time and let them leave only after they have confirmed their training dates and times with you and you have given them their individual confirmation slips]

Learner-Generated Extended Training Protocol

Day Two

I. Introduction and Review

I would like to welcome you all back to day two of training.

Let's begin with a recap of what we learned from day 1 training.

When solving problems using the analogical problem solving method, what are the stages that you would go through?

[elicit responses from each student----write down steps on a blank overhead and re-cap them in this order: goal, objects, and constraint identification, search for and retrieval of analogous problem's solution, application of analogous solution, generate a solution strategy to the target problem]

Before we begin, let me remind you that as an added bonus for your participation in this entire study, you will have the opportunity to win up to $225.00 in cash and prizes.

First, as I have told you, you may win one of four $25.00 gift certificates just for completing this study.

Second, depending on your performance during the third training session and final testing session you have the chance to earn up to four chances for a grand prize of $200.00. For each qualifying problem that you solve correctly on the third day of training and during the testing session you will earn one chance to win $200.00.

As an example, if you solve one of the two problems correctly on day three and two problems during the testing session, you will have three chances to win the grand prize.

What will be important for you to remember is that I will be teaching you things during this training session that you will need to remember to be able to correctly solve problems during sessions three and four. So, the more you pay attention and learn, the more chances you will have to win.

Today, we will learn how to use analogies that do not contain the complete information about solving a problem.

A complete problem is one that provides you with the initial and final goal states, objects, and constraints, strategies, and a solution. All of the analogies we used during the last training session would fall into this category.

Can anyone tell me what a partial analogy might consist of?

[elicit responses from each student--should indicate that a partial analogy is missing one element of a complete analogy--usually the solution strategy]

To determine how we might use partial analogies, let's begin by having you solve a practice problem.

[hand out cord problem and read out loud]

Do any of you remember an analogy from your first day of training that may help you solve the cord problem?

[elicit responses from each student--should say birthday problem]

That's right, the birthday problem.

[hand out birthday problem]

On the sheet of paper labeled "cord problem," write down anything you notice about the cord problem in comparison to the birthday problem.

[give students 3 minutes to complete this task]

Great, let's have everyone tell the whole group one thing that they noticed about these problems.

[elicit responses from each student and write responses on a blank overhead--possible prompts, if needed-- What similarities did you notice between these problems' goal states? How about the objects they used in the problems? Did you notice any similarities between constraints in the problems? How about the amount of information each problem provided you with--any differences or similarities?]

How could you make use of the information found in the birthday problem?

[elicit responses from each student]

How are these two problems different from the situations and how you solved problems during session one?

[elicit responses from each student--should indicate that previous problems gave solution strategy and you simply applied the strategy to the target problem--in this situation you must solve the problem without a solution strategy]

Now, take a few minutes to solve the cord problem.

[give five minutes to solve cord problem unless everyone finishes sooner]

Let's see how your solution compares to the correct solution for the cord problem.

[put up solution and read out loud]

Go ahead and correct your solution strategy using the same paper.

Even though the birthday problem did not provide a solution strategy, was it still helpful to you? How did you use the partial analogy?

[elicit responses from each student]

That's right, by trying to solve the birthday problem first, you can take the generated solution strategy and apply it to the cord problem.

II. Practice

Let's continue working with partial analogies with this first set of three analogies.

[hand out set one to each student]

Please read through each problem and solution as I hand these out but do not write on these forms.

[wait until each student has read through all three analogies]

Now, let's try to solve this practice problem.

[hand out jungle problem and read out loud]

First, on the piece of paper labeled "jungle problem" I want you to write down anything you notice about this problem in comparison to the three analogies I just presented to you.

[hand out problem--give students 3 minutes to complete this task]

Great, let's have everyone tell the whole group one thing that they noticed about these problems.

[elicit responses from each student and write responses on a blank overhead--possible prompts, if needed-- did you identify one analogy that was more similar than the others to the pigs problem? What similarities did you notice between these problems' goal states? How about the objects they used in the problems? Did you notice any similarities between constraints in the problems? How about the amount of information each problem provided you with--any differences or similarities?]

Did you identify one problem that would be more appropriate to use as an analogy if I were to ask you to solve the jungle problem?

[elicit responses from each student--should state the gala problem]

Right, the inaugural gala problem.

How could you make use of the information found in the inaugural gala problem?

[elicit responses from each student]

On the same sheet of paper, take a few minutes to solve the jungle problem.

[give 5 minutes to solve the problem]

How did everyone do?

[elicit response from everyone]

How do your answers compare to the correct solution to the jungle problem?

[put up correct solution on overhead and read out loud]

Go ahead and correct your solution strategy using the same paper.

Even though the inaugural gala problem did not provide a solution strategy, was it still helpful to you? How did you use the partial analogy?

[elicit responses from each student]

That's right, by trying to solve the inaugural gala problem first, you can take the generated solution strategy and apply it to the jungle problem.

Okay, let's practice some more with analogy set number two.

[hand out set two to each student]

Please read through each problem and solution as I hand these out but do not write on these forms.

[wait until each student has read through all three analogies]

Now, let's try to solve this practice problem.

[hand out Trump Suit problem and read out loud]

First, on the piece of paper labeled "Trump Suit" I want you to write down anything you notice about this problem in comparison to the three analogies I just presented to you.

[hand out problem--give students 3 minutes to complete this task]

Great, let's have everyone tell the whole group one thing that they noticed about these problems.

[elicit responses from each student and write responses on a blank overhead--possible prompts, if needed-- did you identify one analogy that was more similar than the others to the Trump Suit problem? What similarities did you notice between these problems' goal states? How about the objects they used in the problems? Did you notice any similarities between constraints in the problems? How about the amount of information each problem provided you with--any differences or similarities?]

Did you identify one problem that would be more appropriate to use as an analogy if I were to ask you to solve the Trump Suit problem?

[elicit responses from each student--should state the ants problem]

Right, the Wine Merchants problem.

How could you make use of the information found in the Wine Merchants problem?

[elicit responses from each student]

On the same sheet of paper, take a few minutes to solve the Trump Suit problem.

[give 5 minutes to solve the problem]

How did everyone do?

[elicit response from everyone]

How do your answers compare to the correct solution to the Trump Suit problem?

[put up correct solution on overhead and read out loud]

Go ahead and correct your solution strategy using the same paper.

Even though the Wine Merchants problem did not provide a solution strategy, was it useful to you? How did you use the partial analogy?

[elicit responses from each student]

That's right, by trying to solve the Wine Merchants problem first, you can take the generated solution strategy and apply it to the Trump Suit problem.

Did you find this to be a useful analogy with which to solve the Trump Suit problem? Were you able to generate a correct solution strategy to the Wine Merchants problem and then apply this strategy to the Trump Suit problem? In comparison to the previous practice problem and its analogy, would it be more difficult to generate a correct solution strategy for the Trump Suit problem?

[elicit responses from each student]

Yes, it would because there could be several possible correct solution strategies for the Wine Merchants problem. Using a partial analogy may not always lead to a correct solution strategy for the target problem, but it can provide a solid starting point and may in fact lead you to a correct solution strategy.

One final point is that analogies come by recalling previously seen problems and they are not necessarily always given to us at the time of problem solving.

So the first best step, after identifying the problems' goal, is to ask yourself "have I ever seen a problem like this before?" and retrieve the relevant information from memory.

You all did a really good job at following the analogical problem solving process.

First, you determined the problems' goal, identified any similarities and differences between two problems, you attempted to apply the analogical strategy and solution to the problem you were solving, you modified the solution if necessary, and, finally, you correctly solved the problems.

III. Conclusion

That concludes the second day of our problem-solving study. I want to thank each of you for participating. As I said before, I have a piece of paper for each of you that lists the day, date, time, and room of your next session.

Remember, it is extremely important that each of you participate in the remaining sessions, so please look over these days and times to make sure you can attend.

As you have been told, you will receive extra credit points when you complete the study, so not only are you helping us out--you receive something in return!

And, as I have told you before, you may win one of four $25.00 gift certificates for completing the study, and you may win up to four chances to win the $200.00 grand prize depending on the number of qualifying problems you solve correctly during sessions three and four.

One final note, during the next few weeks it is vital that you do not discuss this training, the testing you will complete, or your chance to win the grand prize of $200.00 with anyone in this group or anyone else in your Psychology class.

Again, thank you for coming.

If there any no more questions you are free to go after you have picked up your paper and have made sure that your name is written on the back of each paper I handed out to you.

[collect all handouts at this time and let them leave only after they have confirmed their training dates and times with you and you have given them their individual confirmation slips]

Learner-Generated Extended Training Protocol

Day Three

I. Introduction and Review

I would like to welcome you all back to day three of training.

Let's begin with a recap of what we learned from day 1 and day 2 training.

When solving problems using the analogical problem solving method, what are the steps that you would take?

[elicit responses from each student----write down steps on a blank overhead and re-cap them in this order: goal identification, problem representation, retrieval of analogous solution, application of analogous solution]

You also learned how to use complete analogies in solving new problems. Someone tell me what a complete analogy is.

[elicit responses from each student--should state that complete analogies provide the initial and final goal states, objects and constraints, strategies, and a solution]

We also learned about partial analogies. What is a partial analogy?

[elicit responses]

What additional step must you take when using partial analogies?

[elicit responses--should indicate that you must solve the partial analogy first and then apply the solution strategy to the target problem]

Before we begin, let me remind you that as an added bonus for your participation in this entire study, you will have the opportunity to win up to $225.00 in cash and prizes.

First, as I have told you, you may win one of four $25.00 gift certificates just for completing this study.

Second, depending on your performance during this training session and final testing session you have the chance to earn up to four chances for a grand prize of $200.00. For each of the two special problems that you solve correctly during today's session and during the testing session you will earn one chance to win $200.00.

II. Practice

Let's begin today's session with a set of three analogies and one practice problem.

[hand out set one to each student]

Please read through each problem and solution as I hand these out but do not write on these forms.

[wait until each student has read through all three analogies]

Okay, on the piece of paper labeled "marching band" I want you to write down anything you notice about this problem in comparison to the three analogies I just presented to you.

[hand out problem--give students 3 minutes to complete this task]

Great, let's have everyone tell the whole group one thing that they noticed about these problems.

[elicit responses from each student and write responses on a blank overhead-- possible prompts, if needed-- did you identify one analogy that was more similar than the others to the marching band problem? What similarities did you notice between these problems' goal states? How about the objects they used in the problems? Did you notice any similarities between constraints in the problems? How about the amount of information each problem provided you with--any differences or similarities?]

Did you identify one problem that would be more appropriate to use as an analogy if I were to ask you to solve the marching band problem?

[elicit responses from each student--should state the Renshaw problem]

Right, the Renshaw problem.

How could you make use of the information found in the Renshaw problem?

[elicit responses]

Now, take another few minutes to solve the marching band problem.

[give 5 minutes to solve the problem]

How did everyone do?

[elicit response from everyone]

How do your answers compare to the correct solution to the marching band problem?

[put up correct solution on overhead and read out loud]

Did you find the Renshaw problem to be a useful analogy with which to solve the marching band problem?

[elicit responses]

Go ahead and correct your solution strategy using the same paper.

Let's continue by having you solve this next practice problem.

[hand out traveler liar/truth teller problem and read out loud]

Remember, you may earn one chance to win the $200.00 prize by correctly solving this problem.

Go ahead and take a few minutes to solve the traveler problem using the paper titled "traveler problem."

[give five minutes to solve traveler problem unless everyone finishes sooner]

Let's see how your solution compares to the correct solution for the traveler problem.

First, switch papers with the person sitting next to you. I am going to put up the correct solution strategy and I want you to correct the paper in front of you as either correct or incorrect by writing "correct" or "incorrect" in the top right hand corner of the paper.

[put up solution and read out loud]

Go ahead and correct your solution strategy using the same paper.

How many were able to apply the quiz game solution strategy from your first day of training and come to the correct answer?

[elicit responses]

Remember, the first step is to look for similar problems and to use that information to solve new problems.

Okay, here is the second problem with which you may earn a chance to win the $200.00 grand prize.

[hand out king and poison cups problem and read out loud]

Now, take a few minutes to solve the poison cups problem using the paper titled "king problem."

[give five minutes to solve poison cups problem unless everyone finishes sooner]

Let's see how your solution compares to the correct solution for the poison cups problem.

First, switch papers with the person sitting next to you. I am going to put up the correct solution strategy and I want you to correct the paper in front of you as either correct or incorrect by writing "correct" or "incorrect" in the top right hand corner of the paper.

[put up solution and read out loud]

Go ahead and correct your solution strategy using the same paper.

Did anyone use the street vendor problem from day two of training to help you generate a correct solution strategy to this problem?

[elicit responses]

You all did a really good job at following the analogical problem solving process.

First, you determined the problems' goal, identified any similarities and differences between two problems, you attempted to apply the analogical strategy and solution to the problem you were solving, you modified the solution if necessary, and, finally, you correctly solved the problems.

III. Conclusion

That concludes the third day of our problem-solving study. I want to thank each of you for participating. As I said before, I have a piece of paper for each of you that lists the day, date, time, and room of your next session.

Remember, it is extremely important that each of you participate in the final session, so please look over these days and times to make sure you can attend.

As you have been told, you will receive extra credit points when you complete the study, so not only are you helping us out--you receive something in return!

And, as I have told you, you may have the opportunity to win one of four $25.00 gift certificates for completing the study. In addition, you will have two more chances at winning the $200.00 grand prize by solving two problems at the next session.

One final note, during the next few weeks it is vital that you do not discuss this training, the testing you will complete, or your chance to win the grand prize of $200.00 with anyone in this group or anyone else in your Psychology class.

Again, thank you for coming.

If there any no more questions you are free to go after you have picked up your paper and have made sure that your name is written on the back of each paper I handed out to you.

[collect all handouts at this time and let them leave only after they have confirmed their testing date and time with you and you have given them their individual confirmation slips]

Appendix I.

Training Analogies

The Book Burners and Book-Lovers Problem

Three book burners and three book wielding book lovers are on a river bank. The book burners and book lovers need to cross over to the other side of the river. They have for this purpose a small rowboat that will hold just two people (and several books). There is one problem, however. If the number of book burners on either river bank exceeds the number of book lovers on that bank, the book burners will destroy the books of the book lovers. How can all six people get across to the other side of the river in a way that guarantees that they all arrive there with the books intact? It is assumed that all passengers on the boat unboard before the next trip, and at least one person has to be in the boat for each crossing.

Solution:
Begin with either one book lover and one book burner, or two book burners, traveling to the right bank. Then leave one book burner and have either the book lover or the second book burner travel back across to the left bank and pick up the remaining book burner (leaving the book lover on the other side). The two book burners would then travel to the right bank dropping off one book burner for a total of two book burners on the right bank. The third book burner would travel to the left bank, get out of the boat and let two book lovers travel back to the right bank. One book lover would stay at the right bank and one book burner already on the right bank would travel back with the second book lover. Now, you have one book lover and one book burner at the right bank. Next, the book burner would get out of the boat and let the two book lovers return to the right bank. These book lovers would de-boat and let the book burner on the right bank take the boat back to the left bank. Now there are three book lovers on the right bank and three book burners on the left bank. Two book burners would travel to the right bank, one would stay and either the second would travel back to the left bank or one book lover would travel to the left bank and pick up the remaining book burner and travel back to the right bank. Now there are three book burners and three book lovers on the right bank.

The Missionaries and Cannibals Problem

Three missionaries and three cannibals having to cross a river at a ferry, find a boat but the boat is so small that it can contain no more than two persons. If the missionaries on either bank of the river, or in the boat, are outnumbered at any time by cannibals, the cannibals will eat the missionaries. Find the simplest schedule of crossings that will permit all the missionaries and cannibals to cross the river safely. It is assumed that all passengers on the boat unboard before the next trip and at least one person has to be in the boat for each crossing.

Solution:
Begin with either one missionary and one cannibal, or two cannibals, traveling to the right bank. Then leave one cannibal and have either the missionary or the second cannibal travel back across to the left bank and pick up the remaining cannibal (leaving the missionary on the other side). The two cannibals would then travel to the right bank dropping off one cannibal for a total of two cannibals on the right bank. The third cannibal would travel to the left bank, get out of the boat and let two missionaries travel back to the right bank. One missionary would stay at the right bank and one cannibal already on the right bank would travel back with the second missionary. Now, you have one missionary and one cannibal at the right bank. Next, the cannibal would get out of the boat and let the two missionaries return to the right bank. These missionaries would de-boat and let the cannibal on the right bank take the boat back to the left bank. Now there are three missionaries on the right bank and three cannibals on the left bank. Two cannibals would travel to the right bank, one would stay and either the second would travel back to the left bank or one missionary would travel to the left bank and pick up the remaining cannibal and travel back to the right bank. Now there are three cannibals and three missionaries on the right bank.

The Men and Boys Problem

Nine men and two boys want to cross a river, using a raft that will carry either one man or the two boys. Assuming that one person must be in the raft for each river crossing, how many times must the boat cross the river in order to accomplish this goal? (A round trip equals two crossings.)

Solution:
First, the two boys cross; then one boy brings the boat back. Next, the man crosses by himself, and finally, the boy on the far bank returns with the boat. To get all nine men across requires that this sequence be repeated eight more times for a total of thirty-six crossings. At that point, the boat will be on the original bank, and only the two boys will remain. They cross together, thus making a total of thirty-seven crossings.

The Trump Suit Problem

One day Donald Trump found that the provisions of caviar on his yacht were severely depleted. Unfortunately, he was also out of gas and could not travel back to shore to buy more for his party that next evening. So he sent out messengers to announce a generous offer. The first person to bring Mr. Trump a canister of caviar would be given 100 shares of stock in Trump Enterprises. However, the offer would expire at sundown.

Two investors heard the news. Each had a Cigarette (a fast, fancy boat) loaded with large canisters of caviar. They both set out for Trump's yacht at once. An hour before sundown they came to a place where the water level was very low. The first investor drove his boat into the shallow water in a desperate attempt to reach the yacht. But the boat was too loaded down with caviar and could not move fast enough to hover across the low water. Consequently, the boat was beached on the sand bar beneath the water's surface and the investor was stranded with 200 pounds of caviar.

Seeing this, the second (and more conservative) investor decided not to make the same mistake. What did the second investor do?

Solution:
The second investor, seeing the problems the first investor had, decides to empty out all of the canisters of caviar but one, ties them to the front of his boat in a down and outward manner, and heads toward the same direction as the first investor did. This way, not only will the barrels form a raft for the boat, the barrels will be the first to hit the sandbars and will act as warning signals that the boat is getting too close to shallow water. This tactic will allow the second investor to maneuver around the sand bars, deliver Mr. Trump his caviar, and receive his reward of 100 shares of Trump Enterprise stock.

The Wine Merchants Problem

One day a rich man found that his wine cellar was empty. So he sent out messengers to announce a generous offer. The first person to bring the rich man a barrel of wine would be given a brick of solid gold. However, the offer would expire at sundown.

Two wine merchants heard the news. Each had a horse-drawn cart loaded with large barrels of wine. They both set out for the duke's palace at once. An hour before sundown they came to a place where the bridge had been washed out by a raging river. The first merchant drove his horses and cart into the flood in a desperate attempt to reach the other side. But the horses were already exhausted and could not fight the current. The cart overturned, and the horses, wine, and driver were washed away. What did the second merchant do?

Solution:

The second merchant tried a different tactic. He poured the wine out of all but one of his barrels, and lashed them together to form a raft; then he loaded the one full barrel, a horse, and himself on top. He set the raft adrift and floated downstream. In a few minutes the raft came to rest on the shore in front of the town where the rich man lived. The merchant disembarked, loaded the wine barrel on the horse, and led it to the rich man's house. He arrived just as the sun was setting, and collected the gold brick as a reward for his efforts.

The Marching Band Problem

Members of the West High School Band were hard at work practicing for the annual Homecoming Parade. First they tried marching in rows of twelve, but Andrew was left by himself to bring up the rear. The band director was annoyed because it didn't look good to have one row with only a single person in it, and of course Andrew wasn't very pleased either. To get rid of this problem, the director told the band members to march in columns of eight. But Andrew was still left to march alone. Even when the band marched in rows of three, Andrew was left out. Finally, in exasperation, Andrew told the band director that they should march in rows of five in order to have all the rows filled. He was right. This time all the rows were filled and Andrew wasn't alone any more. Given that there were at least 45 musicians on the field but fewer than 200 musicians, how many students were there in the West High School Band?

Solution:
Answer = 145.

The Renshaw Problem

Mr. and Mrs. Renshaw were planning how to arrange vegetable plants in their new garden. They agreed on the total number of plants to buy, but not on how many of each kind to get. Mr. Renshaw wanted to have a few kinds of vegetables, and ten of each kind. Mrs. Renshaw wanted more different kinds of vegetables, so she suggested having only four of each kind. Mr. Renshaw didn't like that because if some of the plants died, there wouldn't be very many left of each kind. So they agreed to have five of each vegetable. But then their daughter pointed out that there was room in the garden for two more plants, although then there wouldn't be the same number of each kind of vegetable. To remedy this, she suggested buying six of each vegetable. Everyone was satisfied with this plan. Given this information, what is the fewest number of vegetable plants the Renshaws could have in their garden?

Solution:
Since at the beginning Mr. and Mrs. Renshaw agree on the total number of plants to buy, 10, 4, and 5 must all go evenly into that number, whatever it is. Thus the first things to do is to find the smallest number that is evenly divisible by those three numbers, which is 20. So the original number of vegetable plants the Renshaws were thinking of buying could be any multiple of 20 (that is, 20 or 40 or 60 or 80 etc.). But then they decide to buy 2 additional plants, that they hadn't been planning to buy originally, so the total number of plants they actually end up buying must be 2 more than the multiples of 20 listed above (that is, 22 or 42 or 62 or 82 etc.). This means that 10, 4, and 5 will no longer go evenly into the total number of plants. Finally, the problem states that they agree to buy 6 of each vegetable, so the total number of plants must be evenly divisible by 6. The smallest total number of plants that is evenly divisible by 6 is 42, so that's the answer.

The General Problem

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. What should the general do in order to capture the fortress?

Solution:
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.

The Parade Problem

A small country was controlled by a dictator. The dictator ruled the country from a strong fortress. The fortress was situated in the middle of the country, surrounded by farms and villages. Many roads radiated outward from the fortress like spokes on a wheel. To celebrate the anniversary of his rise to power, the dictator ordered his general to conduct a full-scale military parade. On the morning of the anniversary, the general's troops were gathered at the head of one of the roads leading to the fortress, ready to march. However, a lieutenant brought the general a disturbing report. The dictator was demanding that this parade had to be more impressive than any previous parade. He wanted his army to be seen and heard at the same time in every region of the country. Furthermore, the dictator was threatening that if the parade was not sufficiently impressive he was going to strip the general of his medals and reduce him to the rank of private. But it seemed impossible to have a parade that could be seen throughout the whole country. What should the general do in order to have the parade seen and heard by everyone throughout the whole country?

Solution:
The general, however, knew just what to do. He divided his army up 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 finally arrived together at the fortress at the same time. In this way, the general was able to have the parade seen and heard through the entire country at once, and thus please the dictator.

The Poker Problem

Three people play a game in which one person loses and two people win each game. The one who loses must double the amount of money that each of the other two players has at that time. The three players agree to play three games. At the end of the three games, each player has lost one game, and each player has eight dollars. What was the original stake of each player?

Solution:
In the third game, one person lost, and two won. The person who lost doubled the money of those who won. Because everyone has ended up with eight dollars, the two people who won the third game must have had only four dollars after two games. Consequently, the person who lost the third game had to pay out eight dollars to the two winners, so the loser of the third game must have had sixteen dollars after two games had been played. Use the same reasoning to find out what happened in the second and the first games.

The Tower of Hanoi 3 Disk Problem

There are three pegs and three disks of differing sizes, A, B, and C. The disks have holes in them, so they can be stacked on the pegs. The disks can be moved from any peg to any other peg. Only the top disk on a peg can be moved, and it can never be placed on a smaller disk. The disks all start out on peg 1, but the goal is to move them all to peg 3, one disk at a time, by means of transferring disks among pegs.

Solution:
Begin by moving disk A to peg 3. Then move disk B to peg 2 and then move disk A to peg 2 so that disk C is still on peg 1 and disk A is on top of disk B which is on peg 2. Next, move disk C to peg 3 and disk A to peg 1. Then move disk B to peg 3 so that it is now on top of disk C. Finally, move disk A to peg 3 and the solution is complete.

The Tower of Hanoi 4 Disk Problem

There are three pegs and four disks of differing sizes, A, B, C, and D. The disks have holes in them, so they can be stacked on the pegs. The disks can be moved from any peg to any other peg. Only the top disk on a peg can be moved, and it can never be placed on a smaller disk. The disks all start out on peg 1, but the goal is to move them all to peg 3, one disk at a time, by means of transferring disks among pegs.

Solution:
Begin by moving disk A to peg 2, then move disk B to peg 3. Next, move disk A to peg three so that it is on top of disk B, and move disk C to peg two. Move disk A back to peg one and then move disk B to peg two so that it is on top of disk C. Then move disk A onto peg two and disk D to peg three. Next, move disk A to peg three and then move disk B to peg one. Move disk A to peg one, disk C to peg three, disk A to peg two, and disk B to peg three. Finally, move disk A to peg three and all four disks should now be on peg three and the solution is complete.

The Three Little Pigs Problem

Recently, the big bad wolf has been harassing the three little pigs a great deal. The three little pigs had a meeting and decided to once again move their home to a better location. After countless hours of searching, they decided to move their home to the very tip top of a hill that has a flat enough surface for a house, so they would be better able to see the big bad wolf coming to blow down their house. There's one small problem. How are they going to move a stone house up a large hill? Your task is to help the three little pigs decide how best to move their stone house up to the very tip top of the hill.

Solution:
One little pig thought they might be able to pull their house up the hill by using a pulley system. To accomplish this, the three little pigs tied one end of a big cable around the house and walked the other end of the cable over the top of the hill. Then, they attached the cable to a mechanical pulley device that was anchored to a big oak tree and would be powerful enough to pull their entire house to the top of the hill. Their solution worked and they successfully brought their house in one piece to the top of the hill and the big bad wolf never bothered them again.

The Hobbits and Orcs Problem

On one side of a river are three hobbits and three orcs. They have a boat on their side that is capable of carrying two creatures at a time across the river. The goal is to transport all six creature across to the other side of the river. At no point on either side of the river can orcs outnumber hobbits (or the orcs would eat the outnumbered hobbits). The problem, then, is to find a method of transporting all six creatures across the river without the hobbits ever being outnumbered.

Solution:
Begin with either one hobbit and one orc, or two orcs, traveling to the right bank. Then leave one orc and have either the hobbit or the second orc travel back across to the left bank and pick up the remaining orc (leaving the hobbit on the other side). The two orcs would then travel to the right bank dropping off one orc for a total of two orcs on the right bank. The third orc would travel to the left bank, get out of the boat and let two hobbits travel back to the right bank. One hobbit would stay at the right bank and one orc already on the right bank would travel back with the second hobbit. Now, you have one hobbit and one orc at the right bank. Next, the orc would get out of the boat and let the two hobbits return to the right bank. These hobbits would de-boat and let the orc on the right bank take the boat back to the left bank. Now there are three hobbits on the right bank and three orcs on the left bank. Two orcs would travel to the right bank, one would stay and either the second would travel back to the left bank or one hobbit would travel to the left bank and pick up the remaining orc and travel back to the right bank. Now there are three orcs and three hobbits on the right bank.

The Apples and Oranges Problem

A grocer ordered a box of apples, a box of oranges, and a box of apples and oranges from his distributor. A week later, the grocer received three boxes of fruit from the distributor. The boxes were labeled “oranges,” “apples and oranges,” and “apples.” The distributor’s representative warned the grocer that although the order had been filled correctly, each label on the boxes was wrong. The grocer realized that he could label each box correctly by selecting one fruit from just one box without looking inside. From which mislabeled box should the grocer select a fruit? Explain.

Solution:
He reaches into the box labeled “apples and oranges” and pulls out a piece of fruit. Whatever fruit he pulls out of that box is the sole contents of the box, because all boxes are mislabeled. If he pulls out an apple from the box mislabeled apples and oranges, then he knows the box contains only apples because they cannot contain a mixture or else the label would be correct, and you are told in the passage that the distributor switched all three labels. Then, through a process of elimination you can correctly label the other two boxes. The box mislabeled oranges must contain the mixture, and the box mislabeled apples must contain the oranges. It might not do the grocer any good to reach into either the box mislabeled apples or the box mislabeled oranges because he cannot be certain that the fruit he pulls out will allow him to correctly label that box. For example, if he reaches into the box mislabeled oranges and pulls out an apple, he doesn’t know whether that box contains solely apples or a mixture of apples and oranges. So, by reaching into the box mislabeled as having the mixture inside and pulling out a piece of fruit, the grocer can correctly label all three boxes. Whatever he pulls out is representative of the sole contents of that box, and through a process of elimination, he can label all three boxes correctly.

The Quiz Game Liar/Truth Teller Problem

On a television quiz program's Bonus Round, the lucky contestant is given the opportunity to select one of two envelopes (a yellow one and a red one). Inside one envelope is a cheque for $25,000. In the other envelope is a slip of paper informing the contestant that he/she has lost everything that was accumulated during the regular game. There are two models, each holding an envelope. The models know the contents of each envelope. The contestant is told that one model always lies and the other model always tells the truth. Unfortunately, the contestant is not told which is which. The contestant can ask only one question to one of the models to decide which envelope to select and hopefully win the $25,000. What question should the contestant ask, and to whom, to guarantee that he/she win the $25,000?

Solution:
After thinking it over for the allotted time limit of 30 seconds, the contestant realized that by asking either model "what would the other model say is the correct envelope" and then picking the opposite envelope, he/she would win the $25,000. Sure enough, he/she asked the question, and is now enjoying a cruise around the Caribbean.

The Casino Problem

A certain casino has three boxes of poker chips. One box is labeled "$5" and contains $5 poker chips. The second box is labeled "$10" and contains $10 poker chips. The third box is labeled "$5 and $10" and contains both $5 and $10 poker chips. One evening a prankster switched all the labels. He told the casino operator that although each label was wrong, he did not alter the contents of any of the boxes. The casino operator realized that by choosing just one chip from one of the boxes without looking inside, he could correctly label all three boxes. How could this be done?

Solution:
He reaches into the box labeled "$5 and $10" and pulls out a chip. Whatever chip he pulls out of that box is the sole contents of the box, because all boxes are mislabeled. If he pulls out a $5 chip from the box mislabeled $5 and $10, then he knows the box contains only $5 chips because they cannot contain a mixture or else the label would be correct, and you are told in the passage that the prankster switched all three labels. Then, through a process of elimination you can correctly label the other two boxes. The box mislabeled $10 must contain the mixture, and the box mislabeled $5 must contain the $10 chips. It might not do the casino operator any good to reach into either the box mislabeled $5 or the box mislabeled $10 because he cannot be certain that the chip he pulls out will allow him to correctly label that box. For example, if he reaches into the box mislabeled $10 and pulls out a $5 chip, he doesn't know whether that box contains solely $5 chips or a mixture of $5 and $10 chips. So, by reaching into the box mislabeled as having the mixture inside and pulling out a chip, the casino operator can correctly label all three boxes. Whatever he pulls out is representative of the sole contents of that box, and through a process of elimination, he can label all three boxes correctly.

The Ants Problem

A colony of ants survived a harsh winter in Logan, Utah, but much to their dismay when winter was over they were very weak and were not able to move heavy pieces of food. The ants could not survive without food so they were forced to head out when spring came and find food. Since they were very weak they could not carry the food on their backs like they normally did, and had to find an alternative way to bring heavy pieces of food into their ant den.

Solution:
One ant thought they might be able to pull the food up the ant hill to the opening to the ant den. To accomplish this they tied one end of a piece of human hair around the piece of food and threw the other end of the hair over the top of the ant hill. Then, the ants wrapped the hair around a tree that served as an anchor and while two ants pulled from one side of the hill, there were two ants pushing the piece of food up the other side of the ant hill. Their solution worked and they successfully brought enough food up the ant hill into their ant den.

The Birthday Party Problem

It was Jane's sixth birthday and her mother wanted to make it a very special day for her. So she organized a big surprise party and invited the neighborhood children without Jane knowing about it. The plan was that the mother who usually picked up Jane after school would be late in order to allow the children time to arrive before Jane. The big day finally arrived. Everything was just about ready, and it was fifteen minutes before the children were supposed to come. Jane's mother was putting the final touches on the decorations for the party room. She was covering the walls and ceiling with balloons and ribbons. Jane's mother was finishing up a decoration pattern. Two final ribbons were left that were dangling from the wood paneling above. She had originally planned to knot these two pieces of ribbon together in order to attach balloons to them. However, whenever she grabbed the end of one ribbon, colored blue, she was not able to grasp the other ribbon, colored pink, at the same time. The ribbons simply were not long enough to be knotted together in this way. It seemed that she would have to abandon her final big of decoration. Suddenly, an idea struck her, and she was able to knot together these two ribbons. How?

Solution:
Jane's mother was just about to give up when she had an idea. She took the pair of scissors that she had been using to cut the various ribbons, and attached the scissors to the end of the ribbon. Next, she took hold of the scissors, and pointing them in the direction of the pink ribbon, swung them vigorously so that this blue ribbon now swayed alternately between the pink ribbon and a nearby wall. She then ran quickly and took the end of the dangling pink ribbon and walked as close to the swinging blue ribbon as possible without letting go of the pink ribbon. She then waited until the swinging blue ribbon came her way and caught it on the upswing. While still holding the pink ribbon, she then removed the scissors from the other blue ribbon and knotted the two ribbons together. Jane's mother just managed to attach all her balloons on these ribbons, completing her decorations, before the children started pouring in. Soon Jane arrived and was genuinely surprised. The party was a great success, and all the mothers complemented Jane's mother on the decorations.

The Fire Chief Problem

One night a fire broke out in a wood shed full of timber on Mr. Johnson's place. As soon as he saw flames he sounded the alarm, and within minutes dozens of neighbors were on the scene armed with buckets. The shed was already burning fiercely, and everyone was afraid that if it wasn't controlled quickly the house would go up next. Fortunately, the shed was right beside a lake, so there was plenty of water available. If a large volume of water could hit the fire at the same time, it would be extinguished. But with only small buckets to work with, it was hard to make any headway. The fire seemed to evaporate each bucket of water before it hit the wood. It looked like the house was doomed.

Solution:
Just then the fire chief arrived. He immediately took charge and organized everyone. He had everyone fill their bucket and then wait in a circle surrounding the burning shed. As soon as the last man was prepared, the chief gave a shout and everyone threw their bucket of water at the fire. The force of all the water together dampened the fire right down, and it was quickly brought under control. Mr. Johnson was relieved that his house was saved, and the village council voted the fire chief a raise in pay.

The Inaugural Gala Problem

Before the Inaugural Gala, organizers were hurriedly trying to decorate the hall. Everything was nearly ready, and it was about ten minutes before the President-Elect was scheduled to arrive. Mr. Smith was decorating the walls and ceiling with balloons and ribbons. He had nearly completed a fancy decoration pattern when he noticed two final pieces of ribbon were left dangling from the tiled ceiling above. He had planned to knot these two final pieces of ribbon together in order to attach balloons to them. However, when he grabbed the end of the green ribbon, he was unable to grasp the end of the blue ribbon at the same time. The ribbons could simply not be knotted together in this way. Since everyone had momentarily left the room, Mr. Smith thought that he would have to abandon this bit of decoration altogether. Suddenly, an idea struck him, and he was able to knot together these two ribbons. How?

Solution:
Mr. Smith was just about to give up when he had an idea. He took the pair of scissors that he had been using to cut the various ribbons and crepe paper, and attached the scissors to the end of the blue ribbon. Next, he took hold of the scissors, and pointing them in the direction of the pink ribbon, swung them vigorously so that this blue ribbon now swayed alternately between the green ribbon and a nearby wall. He then ran quickly and took the end of the dangling green ribbon and walked as close to the swinging blue ribbon as possible without letting go of the green ribbon. He then waited until the swinging blue ribbon came his way and caught it on the upswing. While still holding the green ribbon, he then removed the scissors from the other blue ribbon and knotted the two ribbons together. Mr. Smith just managed to attach all his balloons on these ribbons, completing his decorations, before the guests arrived. Soon the President-Elect arrived and was genuinely surprised. The Inaugural Gala was a great success, and all the organizers complemented Mr. Smith on the decorations.

The Identical Twins Problem

Once there were identical twins who were continually playing pranks on their family, friends, and teachers. The annual school picnic was always a big event for the twins. There were races and other athletic events in which the twins won lots of prizes. One year a new student arrived who was a star runner. The twins wanted to win the main event: the 2-mile race through the woods behind the school. So they secretly devised a plan which would enable them to outdo the newcomer.

Solution:
The day of the race arrived. Each runner was to pick his own path through the woods to a clearing, where a teacher stood posted to determine the winner. One twin entered the race, while the other excused himself on the grounds that he had hurt his leg in an earlier broad jumping event. The race began and the students rushed into the woods. The twin rushed into the woods and waited until the others has passed out of sight. Then he went back to the school using a path hidden from the picnic area. Shortly after, the other twin, who had been hiding behind a rock near the finish line of the race, burst out and ran into the clearing ahead of the other runners. The teacher named him the winner and marveled at the speed of his running. Next year the twins switched places and thereafter maintained their status on this event.

The Jungle Problem

An adventurous explorer traveling through the jungles of Africa decided to stop for the night. Since the jungle he was exploring was full of snakes, he decided to sleep in a hammock-like device suspended over a babbling brook. He began unfolding the blanket that would serve as the base for the hammock. When he finished this, the explorer grabbed two vines hanging down and tied them together. This served as support for one end of the blanket. However, the two vines that were to support the other end presented some difficulty. When the explorer grabbed the end of one vine, it was impossible for him to grab the end of the other vine at the same time. The two vines simply could not be knotted together in this way. The explorer thought he would have to give up and move camp elsewhere because these two vines from above could not be knotted together. Suddenly, an idea struck the explorer and he was able to knot together the two vines.

Solution:
He takes a rock and attaches it to the end of one of the vines. The rock cannot be so heavy that it pulls the vine down and it cannot be that light that it will not allow him to turn the one vine into a pendulum. So, he sets the vine to which he attaches the rock in a swinging motion. Then, while it's swinging, he runs over to the stationary vine, grabs it, and walks with it towards the vine that is now swinging. When the swinging vine comes back to him on the upswing, he can grab it, while still holding the other vine, and attack the two of them together. Because of pendulum motion, this solution works. So, by turning one of the vines into a pendulum, the explorer is able to attach the two vines together.

The Street Vendor Problem

A street vendor sells navy shirts and white shirts. The vendor has two identical boxes, one for the white shirts and one for the navy shirts, and every day he starts out with 15 of each color of shirt. His boss, wanting to play a practical joke on his employee, mixed up the shirts between the two boxes, making sure, though, that neither box was empty. His boss told the janitor about the trick and the janitor in turn told the street vendor. So, the vendor opened up his two boxes before leaving the spot. Upon looking in them both, he realized that his boss had arranged them such that the probability of randomly selecting a navy shirt over a white shirt was maximized. How were the shirts distributed between the two boxes?

Solution:
One box contained 1 navy shirt, and the other box contained 14 navy shirts and 15 white shirts. The reason why this maximizes the probability of selecting a navy shirt is this: If the vendor would reach into the left box, and there is a 50% chance he would randomly do this, then there is a 100% chance that he would pick out a navy shirt. It's the only shirt in the box. Multiply .50 and 1 and you get .50. If he should go to the right box, and there is a 50% chance that he would do this, there is a 14/29 chance of picking out a navy shirt. Multiply .50 and 14/29 together and you get about .25. When you add it all up, you get abut a 75% chance of randomly picking out a navy shirt. If you try any other possible combinations of shirts, keeping in mind that no box may be empty, you will never the a value as high as 75%. So, by putting 1 navy shirt in one box and everything else in the second box, the probability of randomly picking a navy shirt is maximized.

The Traveler Liar/Truth Teller Problem

A traveler comes to a fork in the road and has no idea as to which way to go to reach his destination. There are two soldiers standing at the fork, and they both know which way is the correct way to go. One soldier is from Bedelred and he always lies. The other soldier is from Narex and he always tells the truth. The traveler knows that one soldier always lies while the other always tells the truth. Unfortunately, however, he does not know which is which. He may ask one soldier only one question to find out which direction he should take. What question should the traveler ask, and to whom?

Solution:

The question the traveler should ask to either of the soldiers is this: "What would the other traveler say is the correct way to go to reach my destination?" and then given this answer, the traveler would take the opposite road. Let's suppose the correct road to take is the right fork. Let's suppose that the soldier you happen to ask is the liar. But, remember, you don't know which is which. So, you say to him, "What would the other soldier say is the correct road to take?" You are, in fact, to him, saying, "What would the truth-teller say is the correct road to take?" Well, the truth-teller would say to pick the right road, but since the liar lies, he'll say, "Oh, the other soldier would say to pick the left road" and then given this answer, the contestant would pick the opposite--the right road. Now, suppose the soldier you happen to ask is the truth-teller. So you say to him, "What would the other soldier say is the correct road to choose?" You are, in fact, to him, saying, "What would the liar say is the correct envelope to choose?" Well, the liar would say to pick the left road, and since the truth-teller tells the truth, he'll say, "Oh, the other soldier would say to pick the left road," and then given this answer the contestant would pick the right road. So, asking either soldier what the other soldier would say and then picking the opposite will get the traveler to his destination by traveling the correct road.

The Poisoned Cups Problem

The King of a distant land sentenced an embezzler to death. Being a gambler at heart, the King offered the prisoner a way out. The King's attendant brought the prisoner two identical boxes, 10 cups labeled "poison," which were filled with some poisonous concoction, and 10 cups labeled "water," which were filled with ice-water. The attendant instructed the prisoner to distribute the cups any way he wished between the two identical boxes, but that he may not put all 20 cups into one box. When the task is finished, the King will at random reach into one of the boxes, pull out a cup, and force the prisoner to drink the contents of that cup. How should the prisoner arrange the cups so as to maximize his chances of living (i.e., maximize his chances of drinking water)?

Solution:
One box contained 1 cup filled with water, and the other box contained 9 water cups and 10 poison cups. The reason why this maximizes the probability of selecting a cup filled with water is this: If the King would reach into the left box, and there is a 50% chance he would randomly do this, then there is a 100% chance that he would pick out a cup filled with water. It's the only cup in the box. Multiply .50 and 1 and you get .50. If he should go to the right box, and there is a 50% chance that he would do this, there is a 14/29 chance of picking out a cup filled with water. Multiply .50 and 14/29 together and you get about .25. When you add it all up, you get abut a 75% chance of randomly picking out a cup filled with water. If you try any other possible combinations of cups, keeping in mind that no box may be empty, you will never the a value as high as 75%. So, by putting 1 cup of water in one box and everything else in the second box, the probability of randomly picking a cup filled with water is maximized.

Appendix J.

Testing Analogies

The Radiation Problem

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?

Solution:
The doctor could direct multiple low-intensity rays toward the tumor simultaneously from different directions, so that the healthy tissue will be left unharmed, but the effects of the low-intensity rays will summate and destroy the tumor.

The Jealous Husbands Problem

Three jealous husbands and their wives having to cross a river at a ferry, find a boat but the boat is so small that it can contain no more than two persons. Find the simplest schedule of crossing that will permit all six people to cross the river so that none of the women shall be left in company with any of the men, unless her husband is present. It is assumed that all passengers on the boat unboard before the next trip, and at least one person has to be in the boat for each crossing.

Solution:
Begin with either one husband and one wife, or two wives, traveling to the right bank. Then leave one wife and have either the husband or the second wife travel back across to the left bank and pick up the remaining wife (leaving the husband on the other side). The two wives would then travel to the right bank dropping off one wife for a total of two wives on the right bank. The third wife would travel to the left bank, get out of the boat and let two husbands travel back to the right bank. One husband would stay at the right bank and one wife already on the right bank would travel back with the second husband. Now, you have one husband and one wife at the right bank. Next, the wife would get out of the boat and let the two husbands return to the right bank. These husbands would de-boat and let the wife on the right bank take the boat back to the left bank. Now there are three husbands on the right bank and three wives on the left bank. Two wives would travel to the right bank, one would stay and either the second would travel back to the left bank or one husband would travel to the left bank and pick up the remaining wife and travel back to the right bank. Now there are three wives and three husbands on the right bank.

Appendix K.

Relationship Between Problems and Analogies

Correspondence A

Cannibal problem
Initial state
Goal: transport each cannibal and missionary to the other side of the river
Resources: boat
Constraint: at least one person must be in the boat at all times, boat can only carry two people at a time, cannibals cannot outnumber missionaries or they will eat the missionaries
Solution plan: vary the number of missionaries and cannibals such that cannibals will not outnumber missionaries
Outcome: each cannibal and missionary is transported to the other side of the river

Book Burners problem
Initial state
Goal: transport each book burner and book lover to the other side of the river
Resources: boat
Constraint: at least one person must be in the boat at all times, boat can only carry two people at a time, book burners cannot outnumber book lovers or the book burners will burn the books
Solution plan: vary the number of book burners and book lovers such that book burners will not outnumber book lovers
Outcome: each book burner and book lover is transported to the other side of the river and the books are still intact

Correspondence B

Cannibal problem
Initial state
Goal: transport each cannibal and missionary to the other side of the river
Resources: boat
Constraint: at least one person must be in the boat at all times, boat can only carry two people at a time, cannibals cannot
outnumber missionaries or
they will eat the missionaries
Solution plan: vary the number of missionaries and cannibals such that cannibals will not outnumber missionaries
Outcome: each cannibal and missionary is transported to the other side of the river

Wine Merchants problem
Initial state
Goal: transport the wine, cart, horse, and driver across the raging river
Resources: cart and horse
Constraint: the horse is tired and the river has already washed away a similar driver and his cart
Solution plan: unload some of the barrels of wine, keeping only what is needed for the reward, tying them to the underneath of the cart, and floating safely across the river
Outcome: the wine, cart, horse, and driver are safely transported across the river

Correspondence C

Farmer's Dilemma problem

Initial state

Goal: transport the fox, goose, and corn across the river to the man's house

Resources: boat

Constraint: the boat would only carry two things at a time--the man and one other thing, the fox would eat the goose if left alone with it, the goose would eat the corn if left alone with it

Solution plan: transport the things one at a time in varying orders such that the fox would never be left alone with the goose and the goose would never be left alone with the corn

Outcome: the fox, goose, and corn are all transported across the river to the man's house

Men and boys problem

Initial state

Goal: transport each man and boy to the other side of the river

Resources: boat

Constraint: the boat can carry either one man or two boys at a time

Solution plan: vary the number of trips the men and boys make across the river such that there are never two men, or more or less than two boys attempting to make a crossing at any one time

Outcome: each man and boy is transported to the other side of the river

Correspondence D

Tower of Hanoi 3-disk problem
Initial state
Goal: to move all three disks from peg one to peg three
Resources: three disks of different sizes and three pegs
Constraint: only the top disk can be moved and a larger disk can never be placed on a smaller disk
Solution plan: move the disks to varying pegs such that a larger disk is never placed on a smaller disk
Outcome: each disk is moved from peg one to peg three

Tower of Hanoi 4-Disk problem
Initial state
Goal: to move all four disks from peg one to peg three
Resources: four disks of different sizes and three pegs
Constraint: only the top disk can be moved and a larger disk can never be placed on a smaller disk
Solution plan: move the disks to varying pegs such that a larger disk is never placed on a smaller disk
Outcome: each disk is moved from peg one to peg three

Correspondence E

Hobbits and Orcs problem

Initial state

Goal: transport each hobbit and orc to the other side of the river

Resources: boat

Constraint: at least one person must be in the boat at all times, boat can only carry two people at a time, orcs cannot outnumber hobbits

Solution plan: vary the number of orcs and hobbits such that orcs will not outnumber hobbits

Outcome: each orc and hobbit is transported to the other side of the river

Men and Boys problem

Initial state

Goal: to determine the number of times the boat must cross the river to transport all the men and boys across the river

Resources: boat

Constraint: the boat can carry either one man or two boys

Solution plan: vary the number of men and boys such that there is never more than one man or two boys in the boat

Outcome: each man and boy is transported across the river

Correspondence F

Apples and Oranges problem

Initial state

Goal: determine which box contained the apples and oranges mixture, the apples, and the oranges

Resources: fruit

Constraint: each box is mislabeled

Solution plan: first draw a piece of fruit from the box mislabeled "apples and oranges," second draw a piece of fruit from the second box, and by process of elimination correctly re-label the third box

Outcome: correctly re-label each box of fruit

Casino problem

Initial state

Goal: determine which box contained the $5 and $10 mixture, the $5 chips, and the $10 chips

Resources: gambling chips

Constraint: each box is mislabeled

Solution plan:

Outcome: correctly re-label each box of chips

Correspondence G

Ants problem

Initial state

Goal: determine how to get the heavy food pieces in the ant hole

Resources: ants

Constraint: the ants are not strong enough to move the food on their own

Solution plan: use a piece of human hair as a pulley device

Outcome: transport the heavy food pieces in the ant hole

Three Little Pigs problem

Initial state

Goal: determine how to move the three little pigs house on top of the hill

Resources: pigs

Constraint: the pigs are not strong enough to move their house

Solution plan:

Outcome: the three little pigs house is transported to the top of the hill and they are out of danger of the big bad wolf

Correspondence H

Birthday problem

Initial state

Goal: tie together the ends of the two ribbons

Resources: ribbons

Constraint: you cannot reach one ribbon while holding the other one

Solution plan:

Outcome: the ends of the ribbon are tied together

Cord problem

Initial state

Goal: tie together the ends of two cords

Resources: cords, weights, pliers, extension cords, chairs, tables, poles, clamps

Constraint: you cannot reach one cord while holding the other

Solution plan:

Outcome: the ends of the cords are tied together

Correspondence I

Inaugural Gala problem

Initial state

Goal: tie the ends of two ribbons together

Resources: ribbons

Constraint: you cannot reach one ribbon while holding the other

Solution plan:

Outcome: the ends of the two ribbons are tied together

Jungle problem

Initial state

Goal: tie the ends of two vines together

Resources: vines

Constraint: you cannot reach one vine while holding the other

Solution plan:

Outcome: the ends of the two vines are tied together

Correspondence J

Wine Merchants problem

Initial state

Goal: transport the wine, cart, horse, and driver across the raging river

Resources: cart and horse

Constraint: the horse is tired and the river has already washed away a similar driver and his cart

Solution plan:

Outcome: the wine, cart, horse, and driver are safely transported across the river

Trump Suit problem

Initial state

Goal: transport the caviar to Mr. Trump's yacht

Resources: boat

Constraint: the water is too shallow for the boat to pass through safely

Solution plan:

Outcome: the caviar, boat, and investor are safely transported to the yacht

Correspondence K

Renshaw problem
Initial state
Goal: determine how many total vegetables to buy
Resources: man, wife, and daughter
Constraint: need an equal number of vegetables in each row
Solution plan: apply the least mean square formula
Outcome: the Renshaws must buy 42 vegetables

Marching Band problem
Initial state
Goal: determine the total number of band members
Resources: boy and band members
Constraint: there must be an equal number of band members in each row
Solution plan:
Outcome: the total number of band members is determined

Appendix L.

Detailed Discussion on Training Session Activities

TC and LC group sessions. During training session number three, students participated in a 2-hour training focused on discussions of types of analogical problems and problem-solving strategies and mastery of strategies. For both groups, the training began with an overview of problem-solving strategies (i.e., trial and error, working backward, working forward) in which three problems (i.e., the Tower of Hanoi three disk problem, the poker problem, and the three little pigs problem) and their solutions strategies were presented. Next, students were instructed on how to use analogical problem-solving processes using the Tower of Hanoi three disk problem as an analogy to solve the Tower of Hanoi five disk problem.

The remainder of the training focused on using analogical problem-solving methods. For the teacher-generated group, this practice included: (a) being presented with groups of two problems (one complete and one partial, or two partials), (b) being instructed on the comparisons that can be made and found between the two problems (i.e., isomorphic versus nonisomorphic, complete versus partial), (c) being trained on the sequence of steps that should be taken when solving a problem, (d) solving each partial problem, and (e) participating in a recap of the steps that were used to derive the correct solution.

For the learner-generated group, this practice included: (a) being presented with the same pairs of problems as used in the teacher-generated session, (b) having the students generate comparisons (e.g., similarities and differences) between these problems, (c) having a discussion of these comparisons leading to students generating their own analogical problem solving processes, (d) solving the problems, and (e) participating in a recap of the steps each student used to derive their solutions. Both teacher and learner-generated training procedures were repeated until all problems are presented, three of which were solved thereby making them complete problems.

Although the sequence of steps was similar in the teacher-generated and learner-generated sessions, the main difference existed in who generated the comparisons between problems and analogical problem-solving strategies. In the teacher-generated group, the instructor generated the comparisons and the analogical problem-solving strategies, while in the learner-generated group, the students generated the comparisons as well as the analogical problem-solving strategies to be used.

TE and LE group sessions. Both the teacher and learner-generated training groups will participated in three one hour training sessions over a seven day period.

Day one. For both groups, the topics covered in day one of training included (a) an overview of problem-solving strategies and (b) how to use complete analogies to solve a target problem. The overview of problem-solving strategies was the same as that discussed in the preceding section, however, the discussion on how to use complete analogies differed slightly from the condensed training groups.

For the teacher-generated group, this discussion included (a) the presentation of one practice problem and a set of three complete analogies (one analogy being isomorphic to the final testing problem, one being isomorphic to the practice problem, and one being isomorphic to day three's first practice problem), (b) being instructed on the comparisons that can be made and found between the isomorphic analogy, the nonisomorphic analogies, and the practice problem, (c) being trained on the sequence of steps that should be taken when solving a problem using an analogy, (d) solving the practice problem, and (e) participating in a recap of the steps that were used to derive the correct solution.

For the learner-generated group, this discussion included (a) being presented with the same practice problem and set of analogies as in the teacher-generated group, (b) having the students generated comparisons (e.g., similarities and differences) between the practice problem and the three analogies, (c) having a discussion of these comparisons leading to students generating their own analogical problem solving processes, (d) solving the practice problem, and (e) participating in a recap of the steps each student used to derive their solutions. For both teacher and learner-generated groups, this discussion was repeated with another practice problem and set of three analogies (one complete analogy being isomorphic to the final testing problem, one complete analogy being isomorphic to the practice problem, and one partial analogy being isomorphic to day two's first practice problem), which concluded day one's training session.

Day two. Day two's training session included (a) a recap of the information presented in day one, (b) instruction on how to use partial analogies to solve novel problem, (c) practice solving a problem that is isomorphic to the partial analogy presented in the second set of analogies on day one, and (d) additional practice solving problems using partial analogies.

After attempting to solve the first practice problem, the teacher-generated group was (a) instructed on the comparisons that can be made and found between the partial analogy and practice problem, (b) trained on the steps that should be taken when solving a novel problem using a partial analogy, (c) presented with a practice problem and a set of three partial analogies (one isomorphic to the final testing problem, one isomorphic to the practice problem, and one nonisomorph), (d) asked to solve the practice problem, and (e) participated in a recap of the steps that were used to derive the correct solution for the practice problem.

For the learner-generated group, this session included (a) being presented with the same initial practice problem as in the teacher-generated group, (b) attempting to solve the initial practice problem, (c) having the students generate comparisons (e.g., similarities and differences) between the practice problem and the partial analogy presented in day one's training, (d) having a discussion of these comparisons leading to students generating their own analogical problem solving processes, (e) being presented with the same practice problem and set of three partial analogies as in the teacher-generated group, (f) having the students solve the practice problem, (g) having the students generate comparisons between the practice problem and the partial analogies, (h) having a discussion of these comparisons leading to students generating their own analogical problem solving processes, and (i) participating in a recap of the steps that were used to derive the correct solution for the practice problem.

For both teacher and learner-generated groups, this sequence of steps was repeated with another practice problem and set of three partial analogies (one isomorphic to the final testing problem, one isomorphic to the practice problem, and one isomorphic to day three's second practice problem), which concluded day two's training session.

Day three. Day three's training session included (a) a recap of the information presented in day's one and two, (b) practice solving a problem that is isomorphic to the complete analogy presented in the first set of analogies on day one, (c) practice solving a problem that is isomorphic to the partial analogy presented in the second set of analogies on day two, and (d) additional practice solving problems using complete analogies.

After attempting to solve the first practice problem, the teacher-generated group was (a) instructed on the comparisons that can be made and found between the complete analogy and practice problem, (b) trained on the steps that should be taken when solving a novel problem using a complete analogy, (c) presented with a second practice problem to be solved using a partial analogy, (d) trained on the steps that should be taken when solving a novel problem using a partial analogy, (e) asked to solve the second practice problem, and (g) participated in a recap of the steps that were used to derive the correct solution strategies for the practice problems. After the two practice problems were solved, the learners were (a) presented with a set of three analogies (one complete isomorph to the final testing problem, one partial isomorph to the final testing problem, and one complete isomorph to the practice problem), (b) asked to solve the practice problem, and (c) participatedin a recap of the steps that were used to derive the correct solution for the practice problem.

For the learner-generated group, this session included (a) being presented with the same initial practice problems as in the teacher-generated group, (b) attempting to solve the initial practice problems, (c) having the students generate comparisons (e.g., similarities and differences) between the practice problems and the analogies used to solve the problems, (d) having a discussion of these comparisons leading to students generating their own analogical problem solving processes, (f) being presented with the same practice problem and set of three analogies as in the teacher-generated group, (g) having the students generate comparisons (e.g., similarities and differences) between the practice problem and the partial analogy presented in day one's training, (h) having a discussion of these comparisons leading to students generating their own analogical problem solving processes, (i) having the students solve the practice problem, and (j) participating in a recap of the steps that were used to derive the correct solution for the practice problem. Completion of the final practice problem sconcluded day three's training session for both the teacher and learner-generated groups.

Control sessions. Subjects were given adequate time to solve the missionaries and cannibals, hobbits and orcs, and book burners and book lovers problems and were presented with the correct solutions to each of these problems. (During pilot testing, it was determined that for the problems deemed to become complete, 5 minutes was an adequate amount of time for most subjects to derive the correct solution, and for the problem deemed to remain partial, one-and-a-half minutes was not enough time to solve the problem. Thus, this helped to ensure that the problems either became complete or remained partial as discussed in the procedure section.) For three other problems (i.e., the general, parade, and fireman problems), subjects were not given an adequate amount of time8 in which to derive a solution, and they were not exposed to the correct solutions, thus resulting in control subjects having been exposed to three partial and three complete problems. In addition, the control subjects were given an adequate amount of time to solve the traveler, poisoned cups, and marching band problems, all of which are nonisomorphic to the testing problems and are the problems, in addition to the testing problems, for which they may have received entries for the $200.00 drawing upon correct solution generation.

VITA

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EDUCATION:

1998 **Ph.D.** Utah State University, Logan, UT
Psychology/Research and Evaluation Methodology
Title: *The Differential Impact of Type of Training, Amount of Practice, and Type of Analogy on Spontaneous Transfer*

1997 **M.S.** Utah State University
Psychology/Research and Evaluation Methodology
Title: *Analogical Problem Solving: An Exploratory Analysis of the Facilitating Effects of Type of Training, Level of Expertise, and Type of Analogies on Spontaneous Transfer*

1993 **B.S.** Pacific Lutheran University, Tacoma, WA
Psychology

WORK EXPERIENCE:

1997-current **Andersen Worldwide, S.C.: St. Charles, IL**

Senior Evaluation Consultant
Responsibilities include consulting with both internal and external clients to determine information needs, designing research and evaluation studies, leading project teams, collecting evaluation data, and analyzing and reporting both qualitative and quantitative data. Examples of current projects include: an evaluation of both the process and product of a strategic Firm-wide initiative, an evaluation of the impact of an internal program on Firm

culture, an evaluation of the New York Attorney Retention Program's impact on retention and recruiting strategies, and development of tools to be used with Firm-wide expatriate programs to assess client satisfaction.

This role also requires an ability to work in a team-based environment, support internal initiatives (e.g., development of our group's Value Proposition), take a large role in recruiting efforts, and to explore opportunities to grow business with existing and new clients. Responsibilities also include serving as a management "coach" to assist personnel in developing core and specialized competencies.

1994-1997 **Western Institute for Research and Evaluation: Logan, UT**

Project Coordinator

National Junior Achievement Evaluation Coordinated a national evaluation of the implementation and impact of Junior Achievement's elementary and middle grade economics education curriculum. Responsibilities included consulting with clients, arranging and completing national site visits, supervising research assistants, developing training material and data collection instruments, training program directors on how to collect evaluation data, collecting data using both traditional and alternative assessment, and analyzing and reporting both qualitative and quantitative data.

W. K. Kellogg Foundation Cluster Evaluation Coordinated a national cluster evaluation of the W. K. Kellogg Foundation's 2020 Visioning effort. Duties included consulting with project evaluators, arranging and participating in cluster evaluation meetings, attending national symposia, developing and administering questionnaires, moderating focus groups, and analyzing and reporting both qualitative and quantitative data.

Graduate Research Assistant/Database Manager

High Technology Model Evaluation

This evaluation was designed to assess the implementation of the high-technology school model, the impact the model had on various student sub-groups and on teacher and student perception of and comfort with the model, and the feasibility of model continuation. Duties included consulting with school district data managers, developing quantitative and qualitative data collection instruments, managing a large database, and analyzing, collecting, and reporting quantitative data.

Graduate Research Assistant

Interdepartmental Doctoral Program Evaluation
The purpose of this evaluation was to determine how well the interdepartmental doctoral program served its students and to illuminate areas in which the program needed improvement. Duties included supervising research assistants, developing and managing a database, completing personal interviews with College of Education faculty, and assisting with the analysis and reporting of both qualitative and quantitative data.

CARES Project Evaluation
Research assistant for an evaluation of the impact of the CARES program. Responsibilities included supervising research assistants, moderating focus groups, and assisting with analysis and reporting of qualitative data.

SPSS-pc Trainer

Responsibilities included developing a training program for graduate students on how to use SPSS-pc in the management and analysis of evaluation data.

Focus Group Trainer

Responsibilities included developing a training program on how to use focus groups to evaluate programs, products, and training sessions. This training included background information on what focus groups consist of, the roles participants, moderators, and co-moderators play in focus groups, and how to analyze and report focus group data.

1994-96 **Utah State University: Logan, UT**

Project Director

Organizational Analysis of the Sports Academy and Racquet Club
This analysis was completed in conjunction with the Department of Management and Human Resources and assessed, through a variety of perspectives, the extent to which the company adhered to its mission statement. Responsibilities included contacting the client, supervising research assistants, developing and administering questionnaires and personal interviews, and analyzing and reporting both qualitative and quantitative data.

Instructor

Introduction to Evaluation: Evaluation Models and Practical Guidelines
Responsibilities included developing lecture material and instructing graduate students on evaluation theories, models, and applications, and developing and grading mid-term and final exams. During this course, distance learning students were exposed to a variety of case studies and in-class activities using various evaluation models and data collection techniques, and were required to develop a proposal for or complete an evaluation project report.

Guest Lecturer

Introductory Psychometrics
Duties included preparing and delivering lecture material on reliability measures.

Graduate Teaching Assistant

Educational Psychology
Duties included preparing and presenting laboratory lecture material and in-class exercises, grading bi-monthly papers, proctoring examinations, giving final grades, and guest lecturing to the larger class on selected topics.

1994 **Organizational Research Services: Bellevue, WA**

Project Director

Tacoma Community College Survey of Student Alcohol Use Rates
Directed a survey of student alcohol use rates and awareness and use of the on-campus Wellness Center. Duties included consulting with the client, developing an evaluation design and proposal, developing a personal interview protocol, supervising research assistants, managing the project budget, and collecting, analyzing, and reporting quantitative data.

Tacoma Community College Wellness Center Peer Educator Evaluation
Directed an evaluation of student use of and satisfaction with the on-campus Wellness Center. Duties included consulting with the client, developing an evaluation design and proposal, developing a focus group guide and telephone questionnaire, supervising research assistants, moderating focus groups, managing the project budget, and collecting, analyzing, and reporting both qualitative and quantitative data.

1993-94 **Center for Social Research: Tacoma, WA**

Project Coordinator

United Way STEPS to Career Success Evaluation
Coordinated a local evaluation of the effectiveness of the STEPS to Career Success program in enhancing family functioning and success. Duties included consulting with the client, developing and administering personal and telephone interview guides, supervising research assistants, training program personnel on data collection and management, and bookkeeping.

Family Center at Elk Plain Needs Assessment
Coordinated a needs assessment of the Elk Plain Family Center. Duties included developing and administering questionnaires, training program personnel on data

collection and management, bookkeeping, and analyzing and reporting quantitative data.

Family Center at Elk Plain Evaluation of Service Providers
Coordinated an evaluation of Elk Plain Family Center service providers' satisfaction levels. Duties included developing and administering personal and telephone interviews, selecting the sample, bookkeeping, and analyzing and reporting both qualitative and quantitative data.

City of Tacoma Evaluation of Community Attitudes Toward Public Safety
Coordinated an evaluation of Tacoma citizens' attitudes toward public safety. Duties included coordinating with the client, developing focus group guides, selecting the sample, co-moderating focus groups, bookkeeping, and analyzing and reporting qualitative data.

Research Analyst

City of Tacoma State Route 7 Public Education Campaign Evaluation Research analyst for an evaluation of the effectiveness of the City of Tacoma State Route 7 Public Education Campaign in increasing the awareness of safe driving practices among Tacoma citizens. Duties included assisting with developing the evaluation design, developing the questionnaire, selecting the sample, bookkeeping, and analyzing and reporting quantitative data.

Safe Streets Prevention Partnership Evaluation
Research analyst for the evaluation of the implementation and impact of the Safe Streets Prevention Partnership in reducing crime in Tacoma and developing partnerships with community residents and business leaders. Duties included evaluating community crime prevention symposia, leadership training, neighborhood watch meetings, crime prevention activities, and community awareness workshops. Duties also included developing and administering personal interviews and telephone questionnaires, performing content analysis, supervising

research assistants, bookkeeping, and analyzing and reporting both qualitative and quantitative data.

Council for Prevention of Child Abuse and Neglect Public Education Campaign Evaluation
Research analyst for the evaluation of the effectiveness of the CPCAN Public Education Campaign in raising parental awareness of child abuse and willingness to seek support. Duties included consulting with the client, developing the telephone interview guide, supervising undergraduate and volunteer research assistants, bookkeeping, and analyzing and reporting quantitative data.

Pacific Lutheran University School of Business Marketing Study
Research analyst for the marketing study for the School of Business designed to determine the need for after hours business education among health care professionals. Duties included administering telephone interviews, supervising undergraduate research assistants, and assisting with analyzing and reporting quantitative data.

1992-94 **Pacific Lutheran University: Tacoma, WA**

Project Director

Integrated Studies Program Evaluation
Directed an evaluation of the impact of an integrated studies program on student learning and satisfaction. Duties included analyzing and reporting both qualitative and quantitative data and preparing a manual for future students on how to succeed in the integrated studies program.

Washington State Patrol (WSP) Safety Education Evaluation
Directed an evaluation, using an experimental design, of the impact of the WSP Safety Education elementary grade program on student attitudes toward police officers and their level of knowledge of safety principles. Duties included consulting with the client, designing the study,

developing a test of program material, supervising research assistants, and analyzing and reporting quantitative data.

Research Assistant

Neonatal Auditory Perception of the Maternal Voice
Research assistant on a project designed to examine infant behavioral responses to auditory stimuli. Duties included preparing stimuli, monitoring infant behavior, recording infant responses, and analyzing quantitative data.

Instructor/Course Developer

Graduate Management Admissions Test Preparatory Course
Developed, in conjunction with the School of Business, and was responsible for presenting training material on how to succeed at taking the GMAT. The eight week course was designed to provide students with knowledge of and practice with techniques that would enable them to obtain desired GMAT scores.

Instructor

Graduate Records Examination Preparatory Course
Responsibilities included preparing and presenting training material on how to succeed at taking the GRE. During the eight-week course, students were exposed to a variety of techniques and received practice with taking the GRE.

PROFESSIONAL ORGANIZATIONS:

American Evaluation Association, 1996-present

American Psychological Society, 1996-present

Puget Sound Research Forum, 1993-1994

Western Psychological Association, 1996-present

HONORS AND AWARDS:

Phi Kappa Phi, Inducted 1997

Psi Chi National Honor Society, Inducted 1996

The National Dean's List, 1996/97

Dean's List for Academic Honors, Utah State University, 1994/95/96/97

Outstanding Undergraduate Research Award, Department of Psychology, Pacific Lutheran University, 1993

Named Who's Who Among American High School Students, 1988/89

ELECTED POSITIONS HELD:

Student Representative, Psychology Department, 1995-96/1996-97

Secretary/Treasurer, American Evaluation Association Product Evaluation Topical Interest Group, 1995-1996

VOLUNTEER POSITIONS:

Instructor, Junior Achievement Middle Grade Economics Education Program, 1997

Manuscript reviewer, Evaluation Practice, 1997-present

TRAINING ATTENDED:

Consulting Skills for Evaluators, AEA Conference, 1997

Spirit of Facilitation, Andersen Worldwide, 1997

Path of Dialogue, Praxis Vitality Alliance, 1998

SCHOLARLY WORK:

A. Books:

Ives, D., & Fitzpatrick, J. (1997). A student's companion to Program and Educational Evaluation. New York: Addison, Wesley, Longman.

Ives, D., Worthen, B., & Sanders, J. (1996). A teacher's companion to Program and Educational Evaluation. New York: Addison, Wesley, Longman.

B. Evaluation Reports:

Ives, D., & Powills, J. (1997) *Corporate Purchasing Card Pilot Program Evaluation: Survey Findings*. St. Charles, IL: Andersen Worldwide.

Ives, D., Powills, J., & DiGiulio, S. (1997) *Corporate Purchasing Card Pilot Program Evaluation: Focus Group Findings.*. St. Charles, IL: Andersen Worldwide.

Ives, D., & Wallace, J. (1997) *Arthur Andersen Internal Communications Survey*. St. Charles, IL: Andersen Worldwide.

Ives, D., &Wallace, J. (1997) *A Comparative Analysis of Business Risks and the Virtual Office.* St. Charles, IL: Andersen Worldwide.

Ives, D., Petersen, C., Eggett, B., Chen, S., & Godfrey, S. (1996) *Analysis of the Sports Academy and Racquet Club.* Logan, UT: Utah State University.

Van Dusen, L. M., & **Ives**, D. (1996). *Findings of the Middle School Evaluation.* A formative evaluation report submitted to Junior Achievement. Logan, UT: Western Institute for Research and Evaluation.

Rodgers, P., **Ives**, D., Cybulski, T., & Worthen, B. (1995). *An Evaluation of Project CARES.* Logan, UT: Western Institute for Research and Evaluation.

Worthen, B., Matsumoto, A., Eide, K., **Ives**, D., Judd, D., & Wright, L. (1995). *Evaluation of Utah State University's College of Education Interdepartmental Doctoral Program.* Logan, UT: Western Institute for Research and Evaluation.

Ives, D. E. (1994). *ISP Student Handbook.* Tacoma, WA: Pacific Lutheran University.

Keller, J., **Ives**, D. E., & Reisman, J. R. (1994). *Family Center at Elk Plain evaluation of service provider interviews*. Tacoma, WA: Center for Social Research.

Reisman, J. R., & **Ives**, D. E. (1994). *Overall findings for the Peer Educator Wellness Center Program*. Bellevue, WA: Organizational Research Services.

Reisman, J. R., & **Ives**, D. E. (1994). *Tacoma Community College Wellness Center: Evaluation of Wellness Center presentations*. Bellevue, WA: Organizational Research Services.

Reisman, J. R., & **Ives**, D. E. (1994). *Evaluation of the December, 1993, Conflict Resolution Training Workshop*. Tacoma, WA: Center for Social Research.

Reisman, J. R., Hall, L., & **Ives**, D. E. (1994). *The Public Education Component of the State Route 7 Corridor Safety Project: Pre-test survey results.* Tacoma, WA: Center for Social Research.

Reisman, J. R., **Ives**, D. E., & Petersen, K. (1994). *Tacoma Community College alcohol-use environment: Student survey findings*. Bellevue, WA: Organizational Research Services.

Reisman, J. R., Keller, J., & **Ives**, D. E. (1994). *Needs Assessment for the Family Center at Elk Plain.* Tacoma, WA: Center for Social Research.

Reisman, J. R., **Ives**, D. E., & Hall, L. (1993). *Community attitudes toward public safety in Tacoma*. Tacoma, WA: Center for Social Research.

C. Manuscripts in Progress:

Ives, D. & Van Dusen, L. M. *Analogical problem solving: Factors that facilitate spontaneous generation.*

Ives, D., Van Dusen, L. M., Stowell, S., Willie, D., & Woodmancy, T. *Barriers to analogical problem solving*.

Van Dusen, L. & **Ives**, D. *A psychological profile of tomorrow's teachers*.

Matsumoto, A. & **Ives**, D. *Evaluation misuse: Lessons learned and strategies for prevention*. Paper submitted to Evaluation.

PRESENTATIONS:

A. Papers & Posters Presented at Professional Meetings - International:

Eyre, H. L., Ferguson, T. J., Ives, D. E., Vollmer, R. L., Petersen, D., Alberico, S., & Abbruzzese, D. M. (1998). *The Socialization of conscience by peers: Exactly how do children make each other feel guilty?* Poster accepted for presentation at the 1998 ISSBD Meeting, Berne, Switzerland.

Matsumoto, A., & **Ives**, D. (1995). *Evaluation misuse: Lessons learned and strategies for prevention*. Paper presented at the 1995 International Evaluation Conference, Vancouver, British Columbia, Canada.

Moon, C., & **Ives**, D. E. (1994). *Neonatal right head turns to the maternal voice.* Poster presented at the International Conference on Infant Studies, Paris, France.

B. Papers & Posters Presented at Professional Meetings - National:

Ferguson, T., **Ives**, D., & Eyre, H. (1996). *All is fair in war, but not love: The*

management of emotions in dyadic relations. Poster presented at the 1997 Society for Research in Child Development Conference, Washington, D. C.

Ives, D., & Van Dusen, L. (1997). *Educating the client: A case study analysis*. Poster presented at the 1997 American Evaluation Association Conference, San Diego, CA.

Ives, D., & Van Dusen, L. (1996). *The effects of training, analogies, and expertise on spontaneous transfer*. Poster presented at the 1997 Western Psychological Association Conference, Seattle, WA.

Ives, D., Van Dusen, L., Stowell, S., Willie, D., & Woodmancy, T. (1996). *Barriers to analogical problem solving*. Poster presented at the 1997 American Psychological Society Conference, Washington, D. C.

Masters, K., **Ives**, D., & Shearer, D. (1996). *Religious orientation differentially impacts guilt and hostility*. Poster presented at the 1997 Western Psychological Association Conference, Seattle, WA.

Masters, K., **Ives**, D., & Shearer, D. (1996). *Religious orientation as a mediator of Type A hostility*. Paper presented at the 1997 American Psychological Association Conference, Chicago, IL.

Anderson, D. D., Reisman, J., Hall, L., Petersen, K., & **Ives**, D. (1994). *Family secrets and paternal power: Mothers' and fathers' attitudes toward seeking help to prevent child abuse*. Paper presented at the Northwest Women's Studies Association Conference, Tacoma, WA.

Baird, B., **Ives**, D. E., & Kersten, K. (1992). *An evaluation of the effectiveness of a Washington State Patrol Safety Education Program*. Paper presented at the National Social Sciences Association Conference, San Francisco, CA.

C. Papers Presented at Professional Meetings - Local:

Baird, B., Gold, L., & **Ives**, D. E. (1993). *An evaluation of an integrated studies program*. Paper presented at the 1993 Pacific Lutheran University Faculty Fall Conference, Tacoma, WA.

Reisman, J. R., Schiller, J., Anderson, D., & **Ives**, D. E. (1993). *Community attitudes toward public safety in Tacoma*. Report presented to the City of Tacoma City Council, Tacoma, WA.

D. Workshops:

Baird, B., **Ives**, D. E., & Kersten, K. (1993). *Determining how best to use evaluation findings to improve The Washington State Patrol Safety Education Program*. Two day workshop at the Annual Washington State Trooper Training Session, Safety Education Division, Olympia, WA.

E. Invited Presentations:

Anderson, D., & **Ives**, D. (1994). Invited to speak to the Pacific Lutheran University Woman's Council on gender differences in interpersonal relationships and willingness to seek social support.