# TEACHING ANALOGIES AND METAPHORS TO ENHANCE COMMUNICATION IN INTERDISCIPLINARY AND CROSS-FUNCTIONAL GROUPS

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# Teaching analogies and metaphors to enhance communication in interdisciplinary and cross-functional groups

Akshi Kakar

## Abstract

In interdisciplinary and cross-functional groups and teams, members pool diverse perspectives for the purposes of new product design and innovation, but these different perspectives may cause interruptions in effective communication. This study examines the use of analogies and metaphors as effective communication tools in interdisciplinary group settings.

Analogies and metaphors are an important aspect of our cognitive activities. Communication using analogies and metaphors plays an important role in constructing our knowledge structures. In this study, an instructional tool with group activities has been designed and tested to teach the effective use of analogies and metaphors in interdisciplinary and cross-functional group and team settings. The tool was designed using theories of pedagogy and includes activities for group members. The instructional tool was tested in interdisciplinary group settings. The results from a mixed methods analysis of data the collected are presented as contributions to the research in group communication and analogies and metaphors. The study also identified characteristics of effective analogies that may be used as potential communication tools in interactions between members from different disciplines and functions.

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# Chapter 1. Introduction

## 1.1 Motivation

This study derives its motivation from the gap between the following two streams of research – first, the explicative and generative nature of analogies and metaphors when used in communication; second, the need to encourage shared understanding in interdisciplinary and cross-functional teams via communication.

Analogies and metaphors are an important part of our conceptual system. Some of the most common cognitive activities - reasoning, problem solving, knowledge transfer and negotiating - have been associated with the use of analogies in daily lives (Blanchette & Dunbar, 2001; Dunbar, 2001; Gentner, 2001, 2004; Gentner & Markman, 1997; Holyoak, 1984, 2005). Some researchers have argued that metaphors play a central role in human sense-making and understanding (Cornelissen, 2005; Holyoak, 2005; Lakoff & Johnson, 1980; Oswick, Keenoy, & Grant, 2002). Cognitive linguists Lakoff and Johnson (1980) provide multiple examples from daily linguistic practices to claim that metaphors define the human conceptual system.

Effective team communication is important in building a cohesive team (Agogino, 2002). To work effectively as a team, it is necessary to coordinate and adjust actions to meet other team member's demands (Salas, Burke, & Cannon-Bowers, 2000). Team members need to have common knowledge about the team and task-related processes (Cannon-Bowers & Salas, 2001). Shared knowledge can enhance task performance in that members would be aware of the substance of tasks their counterparts perform (Agogino, 2002; Cannon-Bowers & Salas, 2001). Team interaction through effective communication is pertinent to consolidating team mental models, promoting coordination, situation awareness, performance monitoring and a shared vision among team members especially within teams that function in complex environments

(Salas et al., 2000). Effective communication tools are a necessary medium that can improve performance and productivity among people, and hence this study branches from the canopy of Human Factors studies.

Cornelissen (2005) endorses the domains-interaction model that suggests metaphors can be an effective medium or shared 'generic space' between the different structures or domains of knowledge. This evidence can be invaluable to the area of interdisciplinary studies that underscores the negative effects of functional diversity (Lovelace, Shapiro, & Weingart, 2001).

### 1.2 Purpose and rationale

The primary question of this study was whether analogies and metaphors can be taught to be used in a disciplined manner to facilitate communication across disciplines and functions. The subsequent objective of this study was to enhance communication and hence performance in cross-functional and interdisciplinary teams.

To answer these questions, an instructional tool was developed to use analogies and metaphors as a medium to establish common knowledge across disciplines and functions. This may be in groups and teams. This study tests the tool in nominal groups with members from different disciplines. Hence, stemming from this research background, research hypotheses for this study are stated below:

1. The use of effective analogies and metaphors can be taught
2. Analogies and metaphors improve accuracy and clarity of communication across disciplines and functions.

The instructional tool devised for this study aimed to take learners through the process of generating and applying analogies and metaphors for reasoning, knowledge transfer and

communication. For the purpose of this study, the cognitive process of analogical mapping has been illustrated in Figure 1.

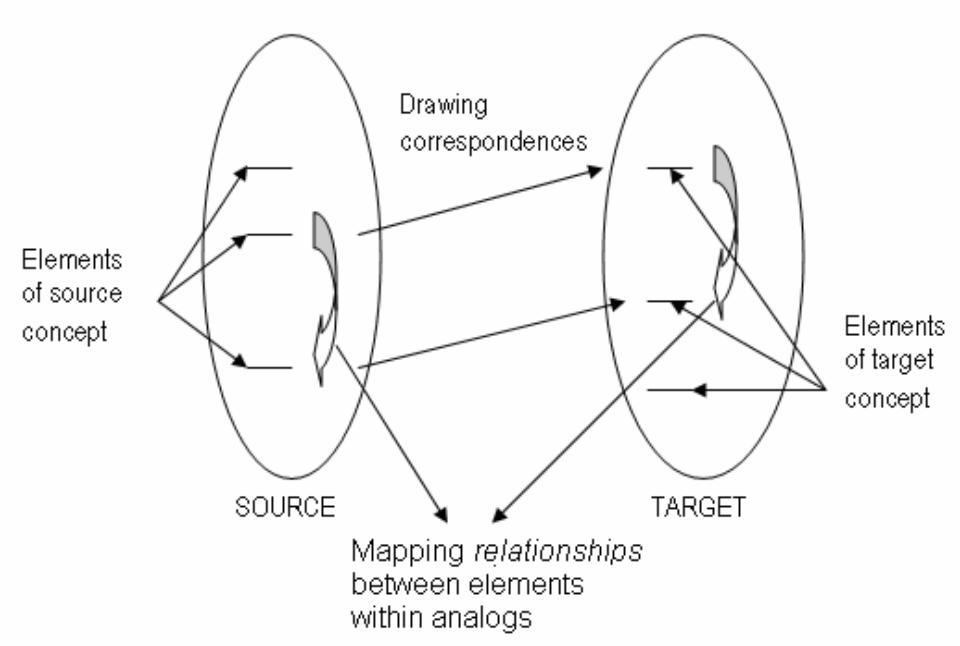



Figure 1. Process of analogical mapping (constructed from information in Holyoak, 2005)

The instructional tool is designed to teach the existing knowledge, roles and benefits of analogies and metaphors. This tool also includes three group activities. Together the activities and instructions consider the two modes of analogical usage (the reception and production paradigms) that have been used in previous studies for teaching analogy production and comprehension (Blanchette & Dunbar, 2000).

The study has drawn knowledge from many disciplines. It orchestrated the concepts of communication, cognition, theories in pedagogy and team studies to develop the instructional tool and test it.

The instructional tool and tests from this study may be valuable to those who work towards enhancing team performance, given that shared understanding is the proximal cause to improved team performance as shown in Figure 2. These results may be directly applied towards

classroom teaching as well.

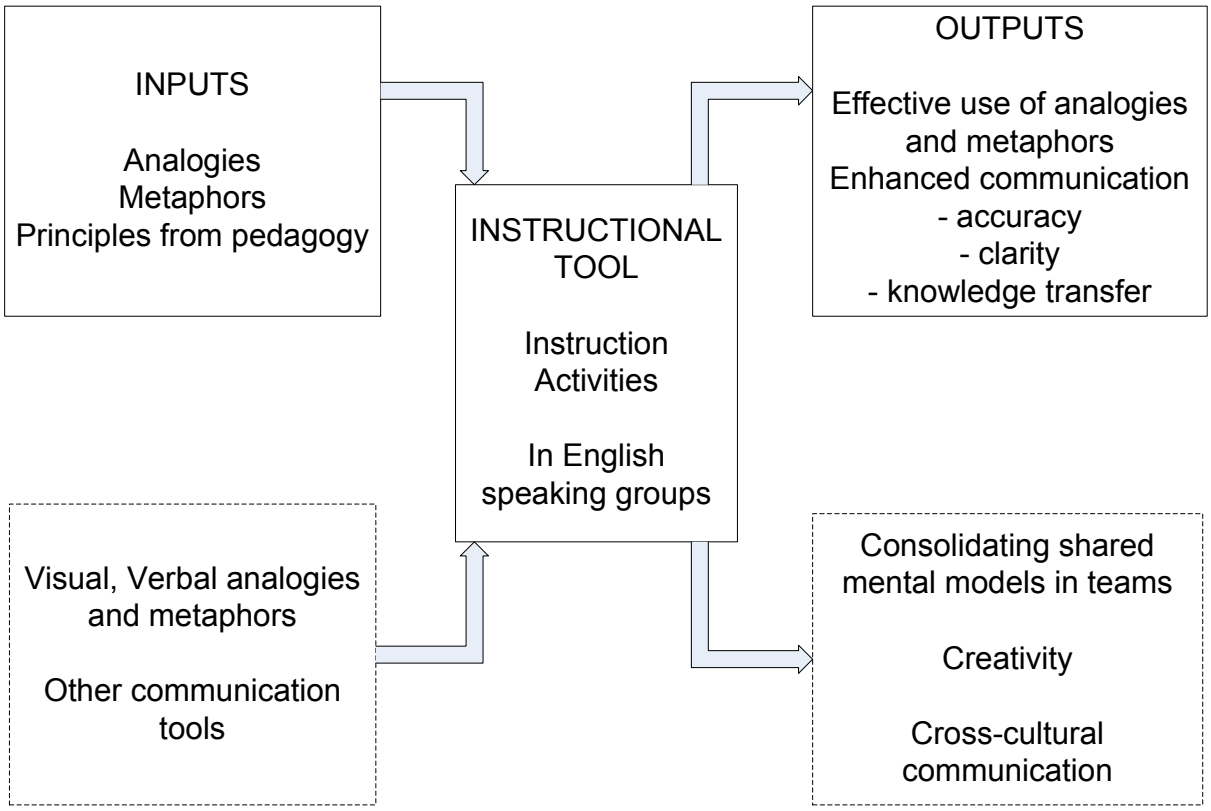



Figure 2. Research model with scope of study and topics of future research

Figure 2 explains the theories and information used to develop the instructional tool. The theories of pedagogy used to design the instructional tool (Bonwell & Eison, 1991; Cantú & Farines, 2007; Ford, Smith, Weissbein, Gully, & Salas, 1998; Hendrikson, 1984; Mayer, 2004; Meloth, 1990; Sherman & Kurshan, 2004; Starnes, 1999; Wickens & Hollands, 1999) have been described in detail in Chapter 2. The boxes in solid line are within the scope of the project while the boxes that are in dotted lines are avenues for future research explained in detail in Chapter 6. Knowledge on the use of analogies, metaphors and the principles of pedagogy helped design the instructional tool. Group activities were adapted from previous studies on analogies and

metaphors. The figure outlines the outcomes of the study and possible avenues for future research that stem from results of this study.

# Chapter 2. Literature review

Given the numerous accounts of how analogies and metaphors can be useful in communication and knowledge transfer across domains, there have been studies encouraging the need to discipline their usage (Oswick et al., 2002). From the research in interdisciplinary studies, it is known that teams with functional diversity face problems due to members having differing perspectives (Lovelace et al., 2001). Effective communication across domains improves the level of shared understanding and hence cohesiveness of interdisciplinary and cross-functional teams (Agogino, 2002; Cannon-Bowers & Salas, 2001; Lovelace et al., 2001). Group members from different disciplines and functions adopt different interpretations and perspectives of group activities (Dougherty, 1992; Lovelace et al., 2001). Groups with disciplinary and functional diversity can "adapt quickly to changing task demands" (Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000, p. 274) relatively quickly if group members draw on their consolidated shared mental models (Cannon-Bowers & Salas, 2001, p. 274; Cannon-Bowers, 1990; Mathieu et al., 2000; Salas et al., 2000; Salas, 1992). Mental models, "organized knowledge structures that allow individuals to interact with their environment" (Mathieu et al., 2000, p. 274), dictate the way individuals interpret and understand information. When team members share mental models they can complement each other's tasks and behaviors to integrate their activities (Mathieu et al., 2000). Effective communication is a medium of consolidating team mental models (Lovelace et al., 2001; Mathieu et al., 2000; Salas et al., 2000; Salas, 1992). Bridging the gap between studies that emphasize the importance of analogies and metaphors and studies that encourage their use, this study aims at teaching the effective use of analogies and metaphors to enhance communication across disciplines and domains.

Communication can be defined in numerous ways, but for the purposes of this study, communication has been defined as "a mediating system" that conveys one's experience or thought of known group of phenomena (Vygotsky, 1988, p. 7). Previous studies of communication emphasize the accuracy and efficiency of production and exchange of meaning that change the behavior of the people communicating (Fiske, 1991). This study aimed at teaching the usage of communication tools that provide the ability to inform and clarify perspectives of people from different backgrounds that leads to convergence of ideas.

Numerous studies illustrate the significance of analogies and metaphors in communication and knowledge transfer (Blanchette & Dunbar, 2001; Cornelissen, 2005; Cornelissen, Kafouros, & Lock, 2005; Dunbar, 2001; Gentner, 2001; Gick, 1980; Holyoak, 2005; Lakoff, 1993; Lakoff & Johnson, 1980; Morgan, 1980; Oswick et al., 2002; Tourangeau, 1991, 1982). Previous research in the field of Cognitive Psychology suggests that analogies and metaphors are essential to the human cognitive system (Dunbar, 2001; Gentner, 2001, 2003, 2004; Gentner & Markman, 1997; Holyoak, 2005). Analogical reasoning is an important component of human cognition that is used by people from all disciplines or functions (Blanchette & Dunbar, 2001). Linguistic psychologists argue that "metaphor is pervasive in everyday life, not just in our language but in our thought and action. Our ordinary conceptual system, in terms of which we both think and act is metaphorical in nature" (Lakoff & Johnson, 1980, p. 3). Organization theorists acknowledge the potential of all tropes - analogies, metaphors, metonyms and binary oppositions - and highlight the need to use them in more disciplined and effective ways (Oswick et al., 2002, p. 301).

## 2.1 Tropes

Tropes are figures of speech in which words are "used in a sense other than the conventional or literal one for which they are intended" (Oswick et al., 2002, p. 295). Analogies, metaphors, metonyms, binary oppositions, paradoxes are examples of tropes (Oswick et al., 2002). Analogies, metaphors, binary oppositions, metonyms and paradoxes are types of tropes (Oswick, Keenoy, & Grant, 2002). This study concentrates on the use and effects of analogies and metaphors to maintain the scope of the study.

## 2.2 Defining analogies

"Analogy is defined as the importation of knowledge from a well-known source onto a less-well-known target by the establishment of correspondences between the two" (Blanchette & Dunbar, 2001, p. 730). The source and the target may be from different domains. "Analogy is a device for conveying that two situations or domains share relational structure despite arbitrary degrees of difference in the objects that make up the domains" (Gentner & Markman, 1997, p. 46). While drawing on knowledge that may be in the form of concepts or situations from different domains and disciplines, "common patterns of relationships" are identified among the constituent elements (Holyoak, 2005, p. 117). Gick & Holyoak (1980) studied the retrieval of source situations from different domains in problem solving in a laboratory setting. They determined that an asymmetry in the initial knowledge forms the basis for knowledge transfer, "using the source to generate inferences about the target" (Holyoak, 2005, p. 117). Some scientific theories are founded on and explained through analogies. One example of this is the planetary model of atomic structure, the Rutherford model proposed in 1911, with electrons orbiting a sun-like nucleus. This theory draws on the knowledge of the planetary system to understand the characteristics of the behavior of sub-atomic particles. The sun is likened to the nucleus of the atom and the electrons around the nucleus to the planets. Subsequently, the

relationship of *magnetic* forces between the sun and the planets is mapped onto the characteristics of the forces that may exist in the atom between the nucleus and the electrons. The *planetary* model of the solar system provided a concrete explanation of the atomic structure by highlighting certain aspects of the atomic structure (Bohr model, 2007; Holyoak, 2005).

## 2.3 Defining metaphors

Metaphors are slightly different from analogies in the way that they work. "The essence of metaphor is understanding and experiencing one kind of thing in terms of another" (Lakoff & Johnson, 1980, p. 5). Metaphors provide an implicit similarity between concepts from semantically distant domains where the two domains are blended but not necessarily mapped as in the case of analogies (Holyoak, 2005; Tourangeau, 1982). For example, "That is the *foundation* of his theory*"* is a commonly used conceptual metaphor of "theories are buildings" (Lakoff & Johnson, 1980, p. 52), while the usage "these facts are the *bricks* and *mortar* of my theory" is a conscious use of the same metaphor "theories are buildings" (Lakoff & Johnson, 1980, p. 53). Similarly, "I cannot invest so much time into this" is an example of a conceptual metaphor 'time is money' (Lakoff & Johnson).

## 2.4 Difference between analogies and metaphors

Analogies and metaphors are similar as they can be used to explain new concepts through similarities between domains (Oswick et al., 2002). Metaphors are slightly different from analogies in the way they work. In comprehending unfamiliar concepts and generating analogies, there is an explicit mapping of knowledge from different domains, while in case of metaphors concepts from "semantically distinct domains" (Holyoak, 2005, p. 120) are blended to form new emergent meanings (Cornelissen, 2005; Cornelissen et al., 2005). Particular characteristics of analogies and metaphors are discussed in the following sections.

## 2.5 Structural and superficial analogies

Two types of correspondences can be made between the source and target analog to create an analogy. Similarities can be drawn on the basis of object features, which are called superficial or surface analogies (Blanchette & Dunbar, 2001). Superficial analogies are generally made between concepts from the same discipline or domain of knowledge. Superficial similarities allow easy retrieval of the source analog, but superficial similarities may obscure the underlying structural similarities which can lead to negative knowledge transfer (Novick, 1988; Thompson, Gentner, & Loewenstein, 2000). Structural analogies draw similarities in the underlying relationships between objects in the source and target analog. Structural analogies are generally from different disciplines and domains of knowledge. Structural similarities highlight and elaborate the basic knowledge structure to cause positive knowledge transfer and storage in long term memory (Blanchette & Dunbar, 2000, 2001; Dunbar, 2001; Gentner, 2001, 2003, 2004; Gentner & Markman, 1997; Holyoak, 2005; Novick, 1988; Ormrod, 2004; Thompson et al., 2000). Likening the atomic structure to the arrangement of the planets in the solar system is a structural analogy which has been used formally to explain the former (Holyoak, 2005). An analogy likening the roles of two presidents would be a superficial analogy, while drawing correspondences between the role of a president and the queen bee in a hive would be a structural analogy.

## 2.6 Effective analogies

Effective analogies correspond to effective communication that involves accurate and substantial knowledge transfer in interdisciplinary group settings (Fiske, 1991). Structural analogies highlight the underlying structures and cause positive knowledge transfer (Blanchette & Dunbar, 2000, 2001; Dunbar, 2001; Gentner, 2001, 2003, 2004; Gentner & Markman, 1997;

Holyoak, 2005; Novick, 1988; Ormrod, 2004; Thompson et al., 2000). Analogies that map relationships between elements of the source and target analog are also identified with positive knowledge transfer (Holyoak, 2005).

## 2.7 Significance and applications of analogies

Analogies are known to stimulate and support numerous cognitive functions. They prominently figure in teaching and learning in the history of science and mathematics. The planetary model of the atomic structure, the hydraulic model of the blood circulation system and the 'billiard-ball' model of gases represent major scientific theories that were described and then evolved through extending analogies and are still taught through analogies.

Analogies play a major role in reasoning and problem solving (Blanchette & Dunbar, 2001; Dunbar, 2001; Gentner, 2001; Holyoak, 1984, 2005). A formalized application of analogical reasoning is legal reasoning, where the knowledge of relevant past cases helps decide new cases (Holyoak, 2005). Analogical encoding involves the comparison of two partially understood situations and fosters the discovery of common principles from the two situations. This common knowledge is easier to retrieve and apply to similar unknown situations and domains (Gentner, 2004). While highlighting commonalities, analogies also highlight differences and hence encourage new approaches and novel solutions to problems and situations (Gentner & Markman, 1997).

## 2.8 Production and comprehension of analogies

The process of analogical transfer involves recognition, encoding, retrieval and mapping between the source and target analogs (Gentner, 2004). A target situation serves as a retrieval cue for a potentially useful source analog. According to the structure-mapping model by Gentner and Markman (1997), the elements of the source and target analogs are aligned and

correspondences between them are drawn. The process of analogical mapping is depicted in Figure 1 in Chapter 1. Correspondences are drawn between the elements and the relationships between each analog onto the other analog (Holyoak, 2005). Structural alignment by drawing correspondences determines the unknown elements or relationships in the target concept. The knowledge of the source analog is then mapped to the unknown target analog to draw inferences about the target analog. The components of analogical reasoning are illustrated in Figure 3 adapted from Holyoak (2005).

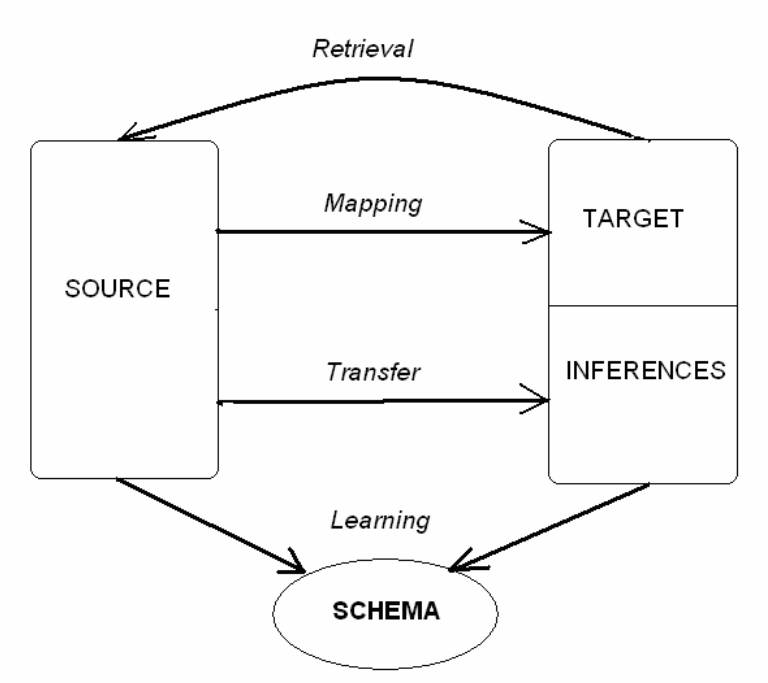



Figure 3. Components of analogical reasoning (adapted from Holyoak, 2005, p. 118)

For example, to explain the structure of an atom, correspondences are drawn between the components of the solar system and subatomic particles. Correspondences are also drawn between the relationships among the components of the solar system and the relationship among the subatomic particles. This example is illustrated in Figure 4.

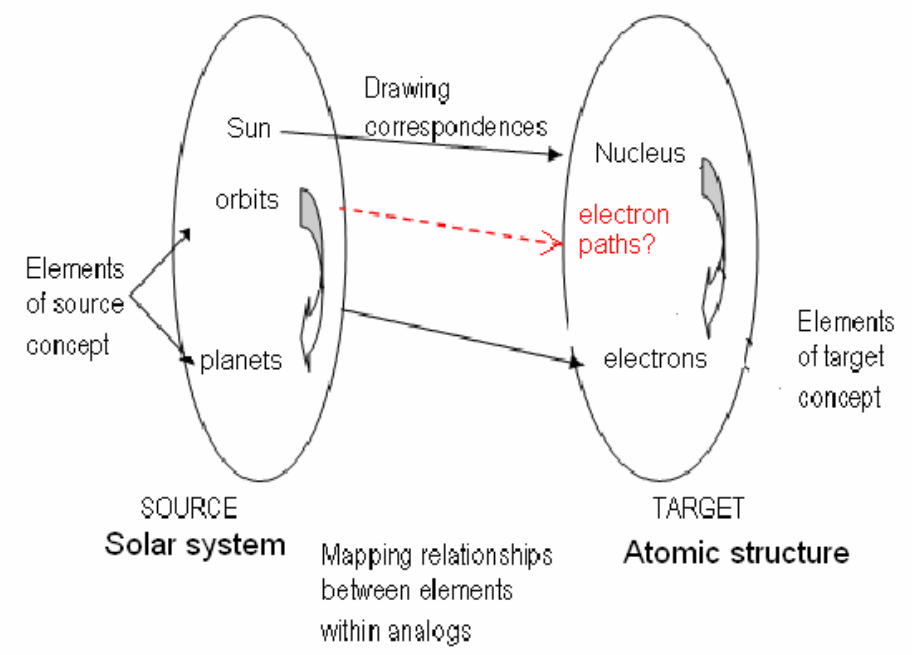



Figure 4. Example illustrating the structure-mapping model (constructed from information in Holyoak, 2005)

This study also considers the two types of analogical usage, the reception and production paradigm. The difference between the two depends on the kind of source analogs retrieved. The reception paradigm is where the participants are given the source and target, and must see the relationship between them rather than generate their own analogies. In this case, researchers in previous studies have observed a surface retrieval of source analogs. A production paradigm is when the participants are given the target analog and are asked to generate the source analogs. Structural retrieval of source analogs have been observed in both individual and team settings in this paradigm (Blanchette & Dunbar, 2000).

### 2.9 Significance and applications of metaphors

Metaphors work a little differently than analogies but perform the same function of drawing the features from a known concept or domain to an unknown idea or concept. "Metaphor involves the conjunction of whole semantic domains in which a correspondence

between terms of concepts is constructed, rather than deciphered, and the resulting image and meaning is creative, with the features of importance being emergent" (Cornelissen, 2005, p. 751). Metaphors highlight the similarities and differences between two concepts of semantically distant domains (Cornelissen, 2005). In this manner, metaphors are known to have effective explicative and generative qualities.

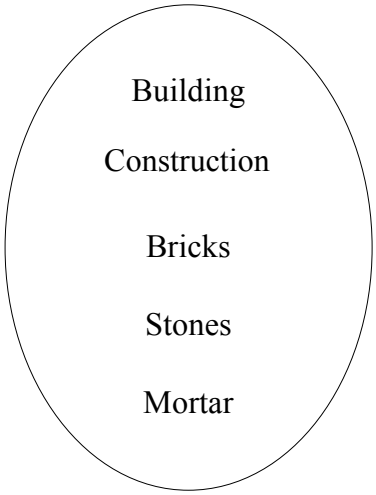
In the late 1900s, metaphors were brought into the limelight of the research arena by two conflicting viewpoints, the constructivists and the objectivists. The objectivist approach considered metaphors to be ornamental and extraordinary literary devices that may or may not enhance understanding (e.g., Pinder & Bourgeois, 1982). Cognitive linguists, Lakoff & Johnson, (1980) demonstrated the constructivist view of metaphors and their role in the human conceptual system. They formed the constructivist viewpoint that rejected the idea of metaphors as secondary, ornamental devices and emphasized their central role in human sensemaking and understanding (Lakoff & Johnson, 1980). This study derives some examples from the constructivist viewpoint for its instructional tool.

### 2.10 Production and comprehension of metaphors

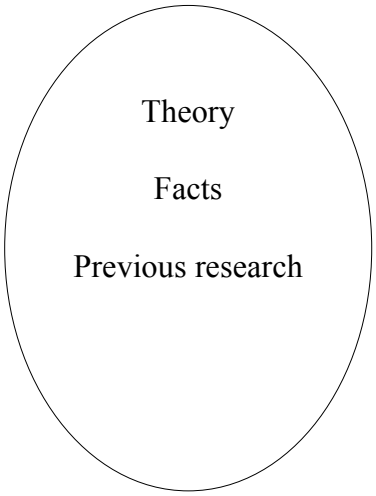
Cornelissen (2005) presented the domains-interaction model to explain the explicative and generative quality of metaphors. Black (1962) had proposed the domains-interaction model on the premise that metaphor involves the "conjoining of whole semantic domains instead of just features of constituents and that metaphor works through considering both the similarities and dissimilarities between correlated domains" (Cornelissen, 2005, p. 756). A "semantic domain refers to a vast organization of knowledge such as our knowledge of travel, life, work, or our organization" (Cornelissen, 2005, p. 757). According to the domains-interaction model, when a metaphor is encountered, a generic space or structure is constructed by blending the similarities

and dissimilarities between the two semantic domains. The process of blending composes elements from the concepts of the two semantic domains and a new emergent meaning is constructed. This emergent meaning modifies our view of the concepts from the two semantic domains (Cornelissen, 2005, p. 758). The construction of a blend of concepts between domains of knowledge emphasizes the role of metaphors as a communication tool across domains and disciplines. The stages of the domains-interaction model (Cornelissen, 2005) are illustrated (in Figure 5) using the example presented by Lakoff and Johnson (1980, p. 53).

Stage 1. Comparison of domains of knowledge and development of generic space

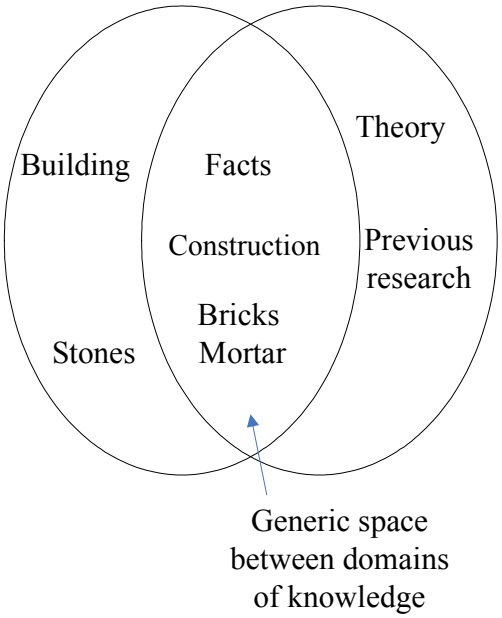



Knowledge domain – building construction



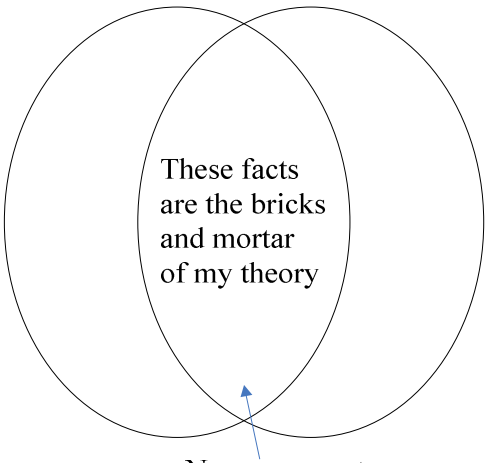

Knowledge domain – research

Stage 2. Development and elaboration of blend




Generic space between domains of knowledge

Stage 3. Emergent meaning




New emergent meaning constructed from two domains of knowledge

Figure 5. Illustration of stages of domains-interaction model of production and comprehension of metaphors (constructed from information in Cornelissen et al., 2005)

### 2.11 Shared mental models in teams

The structure-mapping model and the domains-interaction model illustrate the potential for analogies and metaphors to present a common 'generic-space' between knowledge structures (Cornelissen, 2005; Holyoak, 1984, 2005; Oswick et al., 2002). Interdisciplinary team members integrate their disciplinary knowledge to solve a common problem through continuous communication (Lattuca, 2003). When integrating functional knowledge, they are cross-functional teams. Multidisciplinary group members merely concatenate their disciplinary knowledge (Lattuca, 2003). Essentially, members of these different types of groups and teams have different individual mental models (Lovelace et al., 2001). Another growing field of interest is the construct of 'group-think' in organizations and their abilities/disabilities to communicate (Klimoski & Mohammed, 1994; Lovelace et al., 2001). Klimoski & Mohammed (1994) explain that the interest in group research has passed from social psychology to organizational psychology. Under the umbrella of shared cognition, Cannon-Bowers & Salas (2001) identify about 20 constructs including shared mental models, team mental models, and shared understanding. The shared mental model construct is relevant to many domains in organizational science and has been associated to an array of terms in this stream of research (Klimoski & Mohammed, 1994; Mathieu et al., 2000). Shared mental models in teams are an intersection of the well-structured knowledge that individual team members draw on to interpret information, select their actions and coordinate with other team members (Cannon-Bowers, Salas, & Converse, 1993; Klimoski & Mohammed, 1994; Mathieu et al., 2000). This aggregation of individual team member knowledge – team-related and task-related – has been correlated with

better team performance (Cannon-Bowers & Salas, 2001; Cannon-Bowers et al., 1993; Klimoski & Mohammed, 1994; Mathieu et al., 2000). Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers (2000) explain that apart from the overlap of knowledge among team members, the organization of this knowledge by team members plays a crucial role in team coordination and performance. Analogies and metaphors may present a medium of this generic space between group members in interdisciplinary, multidisciplinary groups and teams.

## 2.12 Principles involved in developing instructional tool

In order to measure the conscious application of analogies and metaphors as communication tools across disciplines, an instructional tool has been developed for this study. This instructional tool applies some of the basic theories and ideas of pedagogy.

Previous studies have shown that metacognition helps people adjust their thinking strategies to learn and solve problems (Ford et al., 1998; Sherman & Kurshan, 2004). Metacognition can be defined as an individual's knowledge of and control over his or her thinking (Ford et al., 1998; Sherman & Kurshan, 2004). Being aware of the cognitive process helps people monitor their progress against the standard cognitive process, determine when and where they are having problems and adjust their learning accordingly (Ford et al., 1998; Sherman & Kurshan, 2004). Previous research suggests that "explicit instruction on knowledge of cognition led to an improvement of participants' knowledge of cognition and that this increase was associated with improved strategy use and comprehension performance" (Ford et al., 1998, p. 220; Meloth, 1990). This method of cognitive management can be encouraged by providing process models (Sherman & Kurshan, 2004).

Instruction that incorporates fundamental concepts and prior knowledge to gradually increase the depth and detail of understanding is the basic principle of spiral curriculum (Cantú

& Farines, 2007). Adopting the spiral approach to teaching ensures "good learning of fundamental and lasting concepts" (Cantú & Farines, 2007, p. 115).

Providing examples while teaching is shown to be effective for learning (Wickens & Hollands, 1999). Providing many examples while teaching helps students "test applications of their understanding in different and unfamiliar situations" (Sherman & Kurshan, 2004, p. 8).

The instructional tool includes activities which involve retrieval, elaboration, evaluation, mapping and higher order synthesis of source and target analogs and similarities between them. These higher order cognitive tasks were intended to promote active learning (Bonwell & Eison, 1991; Hendrikson, 1984; Mayer, 2004). Active learning facilitates learning through activities that involve solving problems, making meaning and building understanding (Starnes, 1999).

The instructional tool also outlines steps that may assist the instructor to lead the production and comprehension of analogies and metaphors. Providing these step-by-step processes enables the participants to control their cognition and consciously use analogies and metaphors. These steps have been defined using verbs from Bloom's Taxonomy of educational objectives (Bloom, 1956; Bloom, 1984; Johnson, 2003) given in Table 1. To define and measure learning through this instructional tool, the process of consciously producing and comprehending analogies and metaphors, which is the final objective, is divided into measurable steps (Brent, 2006).

Table 1. Bloom's taxonomy of educational objectives

| Competence | Skills demonstrated | Verbs |
|---|---|---|
| Knowledge | Basic facts, definitions, events, persons, places, principles, theories, methods and procedures | List, Describe, define, identify, tell, show, label, collect, examine, name, who, tabulate, when, where |
| Comprehension | Understand the meaning of information, Restate in your own words, translate from one form to | Interpret, Summarize, Discuss, Contrast, Describe, predict, associate, extend, estimate |

| | | |
|---|---|---|
| | another | |
| Application | Applying general rules, methods and principles to a specific situation, using appropriate formula/ principle to solve a problem | Apply, demonstrate, calculate, complete, Illustrate, show, solve, examine, modify, relate, change, classify, discover, experiment |
| Analysis | Recognizing the hidden meanings, seeing patterns and identifying components | Analyze, separate, order, explain, connect, classify, arrange, select, compare, infer, divide |
| Synthesis | Create new ideas from knowledge of old ones, relate knowledge from several areas, draw conclusions | Create, combine, generalize, integrate, rearrange, substitute, design, invent, prepare, formulate |
| Evaluation | Compare and discriminate between ideas, assess values of theories and principles, make choices based on reasoned argument | Assess, judge, decide, rank, test, measure, convince, conclude, compare, summarize, recommend, discriminate, grade |

Note: From Benjamin S. Bloom *Taxonomy of educational objectives*.



The competence levels of the Bloom's taxonomy define and measure the levels of learning. Each level is characterized by certain skills demonstrated by students and the verbs used to measure these skills are given in Table 1.

Based on the information derived from the literature search, an instructional tool was developed to teach the conscious and effective use of analogies and metaphors as learning outcomes that could be demonstrated by students and measured by instructors and evaluators. The instructional tool is described in detail in Chapter 3.

# Chapter 3. Methodology

## 3.1 Study objectives

The study aimed to develop an instructional tool for teaching analogies and metaphors to improve communication between people from different disciplines and functions. Participants in groups will be able to:

1. explain unfamiliar concepts using analogies and metaphors
2. enhance their ability to accurately exchange meaning and clarify the perspectives of people from other disciplines and functions.

## 3.2 Experimental Design

### 3.2.1 Participants

Ten senior engineering and management students from different disciplines formed the sample population. These participants, all belonging to different disciplines, were members of two groups working on Green Engineering Capstone course projects. The different disciplines involved were Biological Systems Engineering (BSE), Material Science and Engineering (MSE), Industrial and Systems Engineering (ISE), Civil Engineering, Engineering Science and Mechanics (ESM), and Management. One of the participants used hearing aids to support hearing, and was supported by an interpreter who used American Sign Language (ASL). Participants were formed into groups of two, where both members were from different disciplines. Stratified sampling was used to form interdisciplinary groups for this study yet maintain random selection of group members (Elmes, Kantowitz, & Roediger, 2006). This method ensured that group members were from different disciplines, but the selection and

combination of participants to form interdisciplinary groups was random. These participants were approximately the same age (17-26 years), with 6 women and 4 men.

### 3.2.2 Research hypotheses

The objective of the study was to design and test an instructional tool to improve communication between people from different disciplines and functions; the following were the research hypotheses:

1. The instructional tool provides a medium to inform perspectives during communication across disciplines and functions and corresponds to knowledge transfer.
2. The instructional tool improves the accuracy in exchange of meaning across disciplines and functions.
3. The instructional tool teaches the generation and application of effective analogies and metaphors that inform and clarify the perspectives of people from other disciplines and functions. Effective analogies and metaphors for the purpose of this study have been defined as analogies and metaphors that correspond to accurate and substantial knowledge transfer (Fiske, 1991) between people from different disciplines or functions. Furthermore, structural and extended analogies may be more valuable in knowledge transfer than superficial analogies (Blanchette & Dunbar, 2000, 2001; Bonnardel & Marcméche, 2004; Dunbar, 2001; Gentner, 2001, 2003, 2004; Gentner & Markman, 1997; Holyoak, 2005; Novick, 1988; Oswick et al., 2002).

### 3.2.3 Quasi-experiment design

The study tested the above hypotheses using a quasi-experiment design of one-group pretest-posttest (Cook & Campbell, 1979). The study had one pretest and two posttests to measure the effect of the instruction at every stage.

In Table 2, O represents the observations taken through pre- and posttests. X represents the treatments or instruction given to the participants (Cook & Campbell, 1979; Martin, 2004).

1. $O_1$ – Pretest
2. $X_1$ – Instruction 1 teaching analogies and metaphors
3. $O_2$ – Posttest 1
4. $X_2$ – Instruction 2 teaching the effective use of analogies and metaphors
5. $O_3$ _ Posttest 2

Table 2. Depicting structure of study

| | | | | |
|---|---|---|---|---|
| $O_1$ | $X_1$ | $O_2$ | $X_2$ | $O_3$ |

The study used a one-group pretest posttest design in field settings. The instructional tool was provided to capstone design engineering and management students as part of their course. The effectiveness of the instructional tool on interdisciplinary communication was observed in interdisciplinary student groups. All participants were taken through all activities of the three tests and all participants complete Questionnaire 2. The study included the pretest, posttest 1 and posttest 2. These tests required each member from groups of two to explain a discipline-specific concept to the other members. The listener would then summarize the concept explained in questionnaire 2. In each of the three tests, the speaker would evaluate the summary of the speaker to measure the extent and accuracy of knowledge transfer. The independent variable was the instruction and interdisciplinary group communication the dependent variable. The responses of speakers and listeners were triangulated to measure the dependent variable in the three tests. The Latin square in Table 3 depicts how these tasks of explanation and summarization were

distributed to the different participants. Sample size (n) = 10, $P_1$ to $P_{10}$ were 10 participants in groups of two.

Table 3. Latin square depicting design of quasi-experiment

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Pretest | Explanation and evaluation of summary | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ | $P_6$ | $P_7$ | $P_8$ | $P_9$ | $P_{10}$ |
| | Summarize | $P_2$ | $P_1$ | $P_4$ | $P_3$ | $P_6$ | $P_5$ | $P_8$ | $P_7$ | $P_{10}$ | $P_9$ |
| Posttest 1 | Explanation and evaluation of summary | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ | $P_6$ | $P_7$ | $P_8$ | $P_9$ | $P_{10}$ |
| | Summarize | $P_2$ | $P_1$ | $P_4$ | $P_3$ | $P_6$ | $P_5$ | $P_8$ | $P_7$ | $P_{10}$ | $P_9$ |
| Posttest 2 | Explanation and evaluation of summary | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ | $P_6$ | $P_7$ | $P_8$ | $P_9$ | $P_{10}$ |
| | Summarize | $P_2$ | $P_1$ | $P_4$ | $P_3$ | $P_6$ | $P_5$ | $P_8$ | $P_7$ | $P_{10}$ | $P_9$ |

Number of participants per cell – 2, $P_N = 10$
Test – 3 levels – within subjects
Role in test (explanation/summarize) – 2 levels – within subjects

3.2.4 Reducing threats to validity and reliability in the design of experiment

1. History – Some participants were aware of and used analogies and metaphors in their communication. This was recorded by providing a pretest to measure the extent of usage before the instruction is given.
2. Testing – Testing increases participants' awareness of what is being tested and can be a threat to internal validity when a pretest or multiple test design is used. The act of pretesting can hence influence participants' behavior (Martin, 2004). For the purpose of this study, the instruction informed the participants of the significance of analogies and metaphors to prompt their correct usage. Also, feedback was obtained from participants after the study was complete to determine if participants were applying the communication tools taught. Ethnographic observations of the participants were obtained

to determine if the communication tools were of natural value to the participants. Hence, there is little threat to participant behavior due to testing.

3. Learning – Considering the same group of participants to test the effects of a treatment may be confounded by the effects of learning through the course of the study. Teaching effectively being the purpose of this study, the selection of one-group pretest-posttest design was justified.

## 3.3 Design of instruments

### 3.3.1 Instruments used

The activity timeline in Table 4 explains objectives, outcomes and time taken for each activity.

Table 4. Activity Timeline

| Research goal | Objectives | Activity number | Time (min) | Outcomes |
|---|---|---|---|---|
| To design an instructional tool for teaching the conscious use of analogies and metaphors aimed at enhancing communication across disciplines and functions<br><br>Identify similarities between different domains and functions | • *Retrieve, identify* and *select* relevant source analogs to *identify* similarities between different disciplines and functions using analogies<br>• *Retrieve, identify* and *select* relevant concepts from familiar domains of knowledge to *identify* similarities between different disciplines and functions using metaphors | 1 | 15 | • *Identify* similarities between the problem situation and story<br>• *Map* similarities and *retrieving* cues to *solve* problem |
| | | 2 | 12 | • *Compare* two examples and *determine* common structure<br>• *Distinguish* between analogical encoding and using examples |
| | | 5 | 5 | • *Draw* similarities between disciplines and functions<br>• *Generate* analogies and metaphors from these similarities |
| | • *Generate* and/or *infer* analogy | 3 | 5 | • *Identify* the common relationship between |

| Research goal | Objectives | Activity number | Time (min) | Outcomes |
|---|---|---|---|---|
| | • *Generate* and/or *infer* metaphor(s) | | | elements of the analogies given<br>• *Map* relationship onto another analogy to *generate* analogs<br>• *Generate* analogies with similar relationship |
| | | 4 | 5 | • *Generate* metaphor(s) to *explain* given concept<br>• *Apply* metaphor in sentence |
| | | 5 | 5 | • *Draw* similarities between disciplines and functions<br>• *Generate* analogies and metaphors from these similarities |

Note: The *verbs* in the objectives and outcomes are drawn from Bloom's Taxonomy of educational objectives (see chapter 2)

### 3.3.2 Formative evaluation of instruments

A formative evaluation of instruments to be used in the study was conducted to ensure their face validity. Face validity is ensured when the instruments measure what they are supposed to measure (Martin, 2004).

*Purpose*

The instruments designed for the experiment were tested and validated in order to receive feedback on pretest/posttest instruments and instructional activities. They helped validate the measurement instruments that were designed for the purpose of this study and have not been validated in any previous study. The formative evaluation also provided an estimate of the time required for each activity/test/instruction. Formative evaluation participants were provided the instruments with the instructions as mentioned in Appendix D and were requested to provide feedback about the instruments after completing the activities/instruments provided.

*Study setting*

Participants – The pilot study was conducted in a group with three participants from different disciplines. The three were graduate students and were not involved in the design of the experiment.

Instruments tested –

1. Questionnaire 1
2. Questionnaire 2
3. Rubric 1
4. Activity 3
5. Activity 4
6. Activity 5
7. Questionnaire 3
8. Rubric 2

Material presented to participants -

1. Verbal instructions for the pretest/posttest and the activities were presented to the participants and were supplemented with written material explaining the same
2. A part of the instruction was given to the participants to enable them to perform activities 3, 4, and 5.
3. Written material was presented to participants (in Appendix D).

*Results of pilot study*

Table 5 presents the results of the formative evaluation of instruments tested. Table 5 presents the instrument tested, the approximate time taken by participants corresponding to each instrument, and the feedback received from participants regarding them.

Table 5. Results of instruments tested

| Instrument tested | Approx. time taken (mins) | Feedback/ improvements suggested and implemented |
|---|---|---|
| Pretest/ Posttest | 22 | • Allow flexible level of unfamiliarity for selection of topics<br>• Take instruments on separate sheets<br>• Take blank sheets along with you |
| Questionnaire 1 | 5 | • Reduce Likert scale to 4-point scale to cause forced choice and prevent central tendencies of scores<br>• Request participant names on questionnaire to enable a longitudinal data analysis |
| Questionnaire 2 | 5 | • Reworded instructions to provide direct action points |
| Rubric 1 | 6 | • Received positive feedback<br>• Found the need to provide a results table |
| Activity 3 | 5 | • Reformat presentation |
| Activity 4 | 3 | • Validated concepts and eliminated 'idea' as a concept due to varying perceptions |
| Activity 5 | 5 | • Validated concepts and eliminated 'green house effect' as a concept due to varying perceptions |
| Questionnaire 3 | 7 | • Rearranged sequence of questions asked<br>• Received positive feedback |
| Rubric 2 | 7 | • Reworded last question |

The feedback and improvements suggested in the formative evaluation of the instruments were implemented to refine the instruments before the study was conducted.

3.3.3 Validity of instruments and activities

1. Pretest – The pretest, questionnaire 1 and 2, and rubric 1 have been designed for the purpose of this study. They have been tested for their face validity in the formative evaluation process. Questionnaires 1 and 2 and rubric 1 have been designed on the basis of the levels of understanding provided by the Bloom's taxonomy (Bloom, 1956; Johnson, 2003). The three tests (pretest, posttest 1, posttest 2) interspersed in the instruction emulate the real-world scenario of describing domain and discipline–specific topics to people from other disciplines. This provides a production paradigm while

activities in the instruction complement the reception paradigm of communicating with analogies and metaphors.

2. Posttests 1/Posttest 2 – Questionnaire 3 and rubric 2 have been validated for evaluation and measurement through a formative evaluation. Questionnaire 2 and 3, and rubric 2 have been designed on the basis of the levels of understanding provided by the Bloom's taxonomy (Bloom, 1956; Johnson, 2003).
3. Activity 1 – The radiation problem and the stories provided have been adapted from the study conducted by Gick & Holyoak (1980). The experiment was designed to determine whether participants successfully retrieve the relevant source analog and map it to solve a problem. They defined success when participants spontaneously transferred the analogous solution from one of the stories. The objective for this study is the same as that conducted by Gick & Holyoak (1980). Hence the instruments from this study were adapted.
4. Activity 2 – The contingency contract example is adapted from Loewenstein (1999) (see Appendix B). It has been used to study the concept of analogical encoding in previous studies (Gentner, 2004; Loewenstein, 1999).
5. Activity 3 – Activity 3 draws analogies from daily linguistic practices. This activity has been validated through a formative evaluation.
6. Activity 4 – This activity draws metaphors from daily linguistic practices. Activity 5 has been validated through the formative evaluation.
7. Activity 5 - This activity draws similarities between domains to further apply them in analogy and metaphor.

### 3.4 Design of the instructional tool

The instructional tool bridges the gap between research that examines the explicative, reasoning and generative power of analogies and metaphors (Cornelissen, 2005; Dunbar, 2001; Gentner, 2001; Holyoak, 2005; Lakoff & Johnson, 1980; Oswick et al., 2002; Tourangeau, 1991, 1982). Previous research argues for a conscious, disciplined usage of analogies and metaphors, and the need for effective communication in groups and teams (Agogino, 2002; Burke, Salas, Wilson-Donnelly, & Priest, 2004; Cannon-Bowers & Salas, 2001; Lovelace et al., 2001; Oswick et al., 2002).

The instruction is based on a step-by-step process involved in generating and inferring analogies and metaphors. These steps are drawn from previous research explaining the processes of comprehension of metaphors (Cornelissen, 2005; Gick, 1980; Holyoak, 2005; Tourangeau, 1991, 1982) and reasoning by analogies (Dunbar, 2001; Gentner, 2001; Gick, 1980; Holyoak, 2005; Oswick et al., 2002). These steps have been coined as verbs drawn from Bloom's taxonomy (Bloom, 1984). Drawing verbs from Bloom's taxonomy helps categorize levels and measure learning of analogies and metaphors (Brent, 2006).

The instructional tool is designed on the basis of the following pedagogical theories and practices:

1. Spiral curriculum - Incorporates the existing knowledge that all participants have. In the case of analogies, this study assumes that all participants have taken the basic analogical reasoning tested on Scholastic Aptitude Test (SAT). Analogies are introduced in the format used for the SAT. More information on these is then constructed over this basic information (Cantú & Farines, 2007). Metaphors are introduced with metaphors commonly used in daily linguistic practices.

2. Providing examples - Provides commonly used examples from previous work (Lakoff & Johnson, 1980).
3. Enabling metacognition - Informs participants of the process and significance of analogical reasoning and metaphorical comprehension to enable metacognition. Being able to metacognicize or control one's process of thinking is known to enhance understanding (Sherman & Kurshan, 2004).
4. Ensuring reflection and application of material taught – Instruction engages participants in activities to reflect on and apply what is taught (Schön, 1983).
5. Active learning – The instruction includes activities in groups. These activities are aimed at promoting higher cognitive activity while learning to facilitate learning (Mayer, 2004). These activities involve retrieval, analysis, elaboration, evaluation, and synthesis of information taught while performing them. Involving students in higher-order thinking tasks as part of their instruction promotes active learning (Bonwell & Eison, 1991; Hendrikson, 1984).

### 3.5 Procedure

This section presents the time taken and schedule of the instruments used during the study.

Table 6 summarizes the time taken by each activity, test, and instruction.

Table 6. Study plan

| Component of study | Time taken in minutes (these are conservative estimates) | Test/ Instruction/ Questionnaire | Total time (mins) |
|---|---|---|---|
| Pretest instruction | 10 | Pretest | 35 |
| Pretest (explanation, questionnaires 1, 2 and rubric 1) for n=10 | 25 | | |
| Activity 1 | 15 | Instruction 1 | 67 |
| Activity 2 | 12 | | |
| Activity 3 | 5 | | |

| Component of study | Time taken in minutes (these are conservative estimates) | Test/ Instruction/ Questionnaire | Total time (mins) |
|---|---|---|---|
| Activity 4 | 5 | | |
| Instruction – Define, comprehend, apply, generate analogies and metaphors | 30 | | |
| Posttest 1 instruction | 5 | Posttest 1 | 30 |
| Posttest 1 (explanation, questionnaires 2, 3 and rubric 2) | 25 | | |
| Activity 5 | 5 | Instruction 2 | 35 |
| Instruction – Generate *effective* analogies and metaphors | 30 | | |
| Posttest 2 instruction | 5 | Posttest 1 | 30 |
| Posttest 2 (explanation, questionnaires 2, 3 and rubric 2) | 25 | | |
| Post study questionnaire | 10 | Questionnaire 4 | 10 |
| **Complete study** | | | **207** |

Note: The time taken for each component is a conservative estimate from the pilot study

The instructions 1 and 2 were part of class lectures of the Green Engineering Capstone Design course conducted in early Spring 2008 semester. Since the class met every Monday for 75 minutes, the tests and instruction for this study were spread in the manner presented in Figure 6.

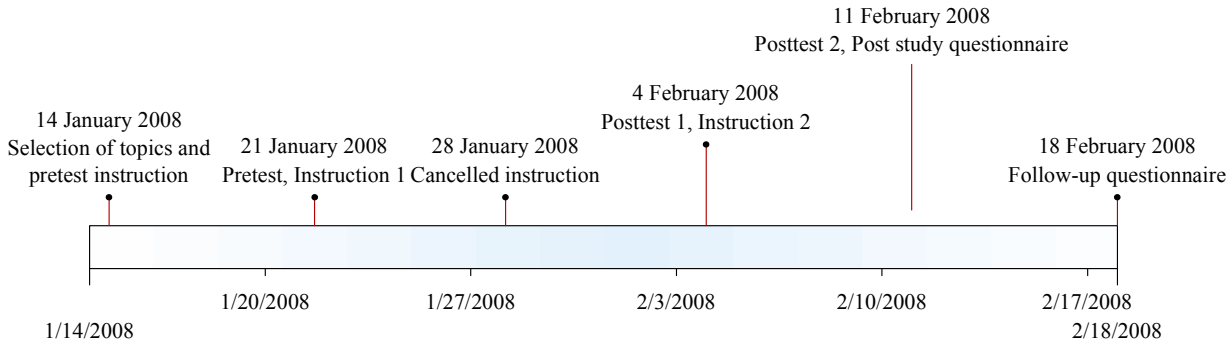



Figure 6. Timeline with data collection milestones

### 3.6 Materials

The instruments, instructional tool and tests for this study are given in Appendix B.

## 3.7 Data analysis

### 3.7.1 Data collected

1. Notes made by participants for explanations in the pretest, posttest1 and posttest 2 – Participants created notes over a span of a week to explain topics chosen by them. These notes also include diagrams made by participants during their explanations.
2. Audio files of participant explanations – Explanations provided by participants for the three tests have been captured on voice recorders as audio files. These files include the content of the interaction within the groups during the pretest and posttests.
3. Questionnaires from tests – Participants provided their feedback about the explanations and their opinion on the extent and accuracy of knowledge transfer during the tests in questionnaires 1, 2, 3 and rubrics 1 and 2. Once the speaker explains the topic, the listener completes questionnaire 1 and 3 providing information about the quality of explanation and usage of analogies and metaphors by the speaker in the pretest and posttests respectively. The listener then summarizes the topic in questionnaire 2 which is evaluated by the speaker using rubrics 1 in the pretest and rubric 2 in the posttest. The speakers evaluate the summary to provide scores on the basis of accuracy and extent of knowledge transfer. To reduce threats due to construct validity and response bias in the questionnaires, the same questions have been asked in different ways. Table 7 enlists the questionnaires used during the study; at what stage were they given to participants and what they were intended to measure.

Table 7. Questionnaires/Rubrics provided during study

| Questionnaire/Rubric | Tests used in | Group member perspective | Measures |
|---|---|---|---|

| Questionnaire/Rubric | Tests used in | Group member perspective | Measures |
|---|---|---|---|
| Questionnaire 1 | • Pretest | Listener | • Speaker's quality of explanation<br>• Listener's confidence in explaining topic before and after explanation<br>• Effect of analogies and metaphors used in the explanation |
| Questionnaire 3 | • Posttest 1<br>• Posttest 2 | | |
| Questionnaire 2 | • Pretest<br>• Posttest 1<br>• Posttest 2 | Listener | • Summary of topic explained by speaker – definition, application and evaluation of application |
| Rubric 1 | • Pretest | Speaker | • Accuracy of knowledge transfer<br>• Extent of knowledge transfer<br>• Usage of analogies and metaphors |
| Rubric 2 | • Posttest 1<br>• Posttest 2 | Speaker | |
| Post instruction questionnaire | • After posttest 2 | Speakers and listeners | • Quality of instruction<br>• Recommendations to improve instruction |
| Follow-up questionnaire | • Two weeks after instruction was complete | Speakers and listeners | • Familiarity of analogies and metaphors after study was over<br>• Usage of analogies and metaphors by participants<br>• Perceived practical value of analogies and metaphors |

4. Post instruction questionnaire – Participants were requested for feedback regarding the instruction provided to them after posttest 2.
5. Follow-up questionnaire – Once the study was complete, participants were revisited to obtain feedback about the usefulness of the communication tools taught. Participants were observed to determine whether they applied and used the communication tools taught.

3.7.2 Procedure for data analysis

Since the instructional tool was tested in a class setting, being a field study more emphasis was given to qualitative analysis that examined each participant's performance and feedback. Both qualitative and quantitative data analyses were conducted. The results from a detailed within subject qualitative data analysis were used to refine the instructional tool.

Simple descriptive statistics were used to depict and summarize the mean performance and responses of the participants across tests. Further, inferential statistical methods were used to determine the probability that the observations made in the study were dependable or happened by chance. Scores from the questionnaires and rubrics for the three tests were analyzed using non-parametric statistical methods. Since the sample size was small (n=10) and the data from the questionnaires was not normal, non-parametric tests were appropriate. A Kruskal-Wallis test (the non-parametric alternative to ANOVA (Montgomery, 2001)) was conducted using JMP 7 to check for significant differences between more than 2 group means. A Mann-Whitney U test was performed to check for significant differences between means from two samples. The critical level of significance for these tests was taken as 0.1. To reduce threats to construct validity, questions were asked in more than one way. The responses to these questions, measuring the same construct were then checked for their convergence or divergence by calculating the Pearson product moment correlation coefficient, r in MS Excel. Questions 8 and 9 on questionnaire 3 measure the listener's perspective of the effect of analogies and metaphors used in the explanation. These questions have been worded to achieve diverging responses. Questions 2 and 3 on the follow-up questionnaire determine if participants used analogies and metaphors after the study was complete. These questions have also been worded to receive diverging responses. A fair to high negative correlation coefficient would support construct validity.

For qualitative analysis, the audio files of explanations from the tests were transcribed and coded using codes created on the basis of previous research and the expected findings. These codes were verified by faculty members, expert in this area of research. The list of codes used to analyze the transcripts has been provided in Appendix C. This analysis was performed using the software QSR NVivo 7. Once the data from the audio files was coded, the coding of the data was cross-checked by a faculty member. Further, the coded data was categorized and relationships were drawn by comparing the coded transcripts across the three tests for each participant.

The questionnaires completed by participants that correspond to the coded explanations were also used to determine the extent and accuracy of knowledge transfer. Scores from questionnaires 1 and 3 provided the listener's perspective on the extent of knowledge transfer while questionnaire 2 and the rubrics provided the speaker's opinions. For each participant, the coded explanation was compared to the listener's perception of effectiveness of communication, and self-assessment of accuracy and extent of knowledge transfer to reduce distortions due to inter-rater bias. The relative responses and in-depth qualitative data analysis for each participant revealed trends in the usage of analogies and metaphors corresponding to effective and ineffective analogies. These characteristics were further emphasized in the refined instructional tool.

The post-instruction questionnaire obtained student opinion on the instructional tool. Student opinion was sought using open ended questions on the aspects of the instruction that were helpful and interruptive in their learning. These ideas were fed into the refined instruction along with the other observations made during the study.

Beyond the data collected during the study, participants were observed for usage of the communication tools taught once the study was over. Students were observed and detailed field

notes made, in class and group meetings, for more than a month after the study was completed. Students were observed for their usage of the communication tools taught. To minimize threats due to the Hawthorne effect, participants were observed in similar conditions for more than three months before the study was conducted. Observations made informed and complemented the inferences made from transcripts and self-reports.

Once the study was complete, the pool of participants was revisited after two weeks of the instruction to determine if the communication tools taught were of any practical value to them. This feedback was received in the form of self-reports (follow-up questionnaire). Participants were questioned about their recognition, usage and perception of analogies and metaphors. This data was collected using the follow-up questionnaire (see appendix B for follow-up questionnaire). Observations of usage of analogies and metaphors were compared to participant responses on their usage of these communication tools.

# Chapter 4. Results

This chapter presents the results from data obtained through questionnaires, rubrics, and audio recordings during the pretest, posttest1 and posttest 2. This section initiates with an insight into participant demographics then presents participant's performance on the three tests. This data is then summarized to answer the main research questions of this study for all the participants and is compared with responses from other questionnaires via box plots. Further, this section presents facts about the findings of the audio recordings and matches them to questionnaire responses to answer the main research questions.

## 4.1 Participant demographics

Participants for the study were ten senior students, nine from different Engineering options and one from Management. These nine participants were from five different engineering departments. All participants were approximately the same age and were enrolled in a Green Engineering capstone design course. The study was included by the instructors as part of the course. These participants had been working in two groups for their capstone design projects for the previous six months. For the purpose of this study, five groups of two were formed in which participants engaged in assigned activities. To preserve the anonymity of the responses of the participants, participants were given pseudonyms. Table 8 provides the participant pseudonyms that were assigned to preserve participant confidentiality, their disciplinary background as well as gender, group partner for the three tests during the course of the study, and the disciplinary topics to be explained in the three tests. Participants were asked to select three topics from their discipline that they are most familiar with and would like to explain to their group partner.

Table 8. Participant demographics

| Group partner letter | Disciplinary background | Gender | Group member | Topics selected for tests |
|---|---|---|---|---|

| Group partner letter | Disciplinary background | Gender | Group member | Topics selected for tests |
|---|---|---|---|---|
| E | Biological Systems Engineering (BSE) | Male | T | 1. Growth of microorganisms in different media<br>2. Growth curve of microorganisms<br>3. Stagnant water |
| L | Civil Engineering (CEE) | Female | Z | 1. Soils<br>2. Wastewater management<br>3. Structures |
| Z | Biological Systems Engineering (BSE) | Male | L | 1. Pharmaceutical industries<br>2. Biotechnology<br>3. Food processing industry |
| A | Biological Systems Engineering (BSE) | Female | J | 1. Food processing – natural packaging material<br>2. Fermentation<br>3. Bacterial growth curves |
| J | Material Science and Engineering (MSE) | Female | A | 1. Decision/design matrix<br>2. Material processing<br>3. Porosity |
| U | Industrial and Systems Engineering (ISE) | Male | C | 1. Demand forecasting<br>2. Project management<br>3. Auditory/visual display design |
| C | Engineering Science and mechanics (ESM) | Female | U | 1. Computational methods<br>2. Solid mechanics<br>3. Bone growth/degeneration (biomechanics) |
| D | Material Science and Engineering (MSE) | Female | B | 1. Crack propagation in notched members<br>2. Effect of particle size distribution on density of ceramics<br>3. Tensile strength testing |
| B | Biological Systems Engineering (BSE) | Male | D | 1. Feather keratin based biodegradable plastics<br>2. Enzyme catalyzing reactions<br>3. Unit operations |
| T | Management | Female | E | 1. Strategic analysis (product/company/competition/ strength and weaknesses)<br>2. Market analysis<br>3. Management theory |

## 4.2 Accurate knowledge transfer

Participant performance in communicating a disciplinary concept was measured in terms of extent of knowledge transfer and accuracy of communication. The speaker explained his/her disciplinary topic which was then summarized by the listener in questionnaire 2. This summary was evaluated by the speaker to test for accurate and sufficient knowledge transfer using rubrics 1 and 2 in pretest and posttests respectively. In the two posttests, speakers were instructed to employ analogies and metaphors in their explanation. Figure 7 presents a box plot depicting an overall trend of the mean score allotted by the all the speakers for the three tests.

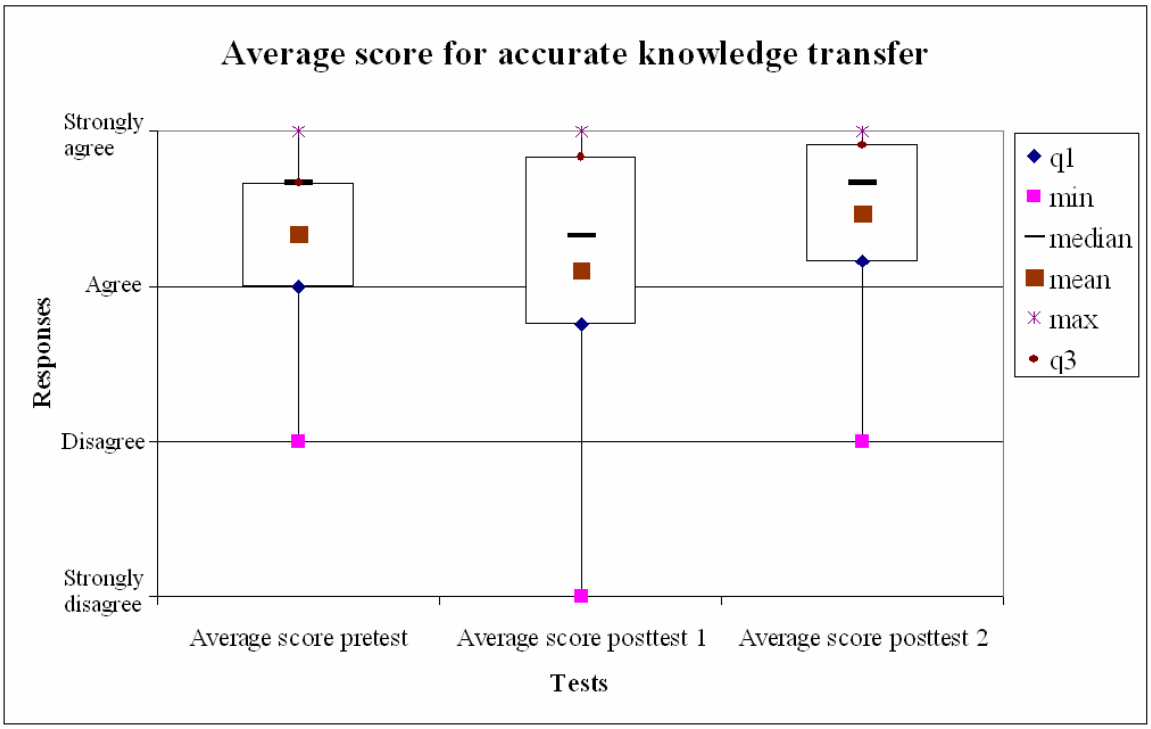



Figure 7. Comparison of mean scores determined on the basis of accuracy in knowledge transfer

As observed from Figure 7, the speakers evaluated the listener's responses and thereby determined the extent to which the explanation provided was effective. For the purpose of this study, effective communication is defined on the basis of accuracy and extent of knowledge transfer. From the box plot in Figure 7, it can be noted that participants on average agreed there

was effective communication in the pretest. The mean scores dropped for posttest 1 when students were given the task of creating analogies and metaphors without the complete instruction of creating effective analogies and metaphors. In the final test, posttest 2, after the complete instruction was provided to participants, more than 50% participants agreed that their responses were effective. It may be noted that a few students did not agree that their communication was effective during the posttests.

A Kruskal-Wallis test was conducted to determine if the differences in the mean scores for all participants across the three tests is significant. A high observed significance probability of 0.64 depicted that the mean scores across the three tests were not significantly different. A Kruskal-Wallis test was then performed to determine significant differences in the mean scores for the three tests across different participants. A low observed significance probability of 0.028 illustrated that the scores provided by different participants were significantly different. This discrepancy in the scores of participants necessitates an in-depth within participant qualitative analysis of responses and data. Further, this being a field study other factors such as student expertise, motivation, and varying difficulty levels of topics chosen by participants demand that emphasis be on the within-subject qualitative analysis. A within-subject qualitative data analysis also highlighted the characteristics of effective and ineffective analogies and metaphors in both the posttests.

### 4.3 Comparing speaker and listener responses to effectiveness of communication

The responses to questionnaires obtained from listeners and speakers on the extent of accurate knowledge transfer are compared in Figure 8. Specifically, responses to questions 3 and 4 on questionnaires 1 and 3 are compared to the scores on rubrics 1 and 2. Table 9 summarizes

the questions to which responses are depicted in Figure 8. In Figure 8, responses strongly agree, agree, disagree and strongly disagree have been given scores of 4, 3, 2, and 1, respectively.

Table 9. Questions requesting listener and speaker perspectives

| Box in Figure 12 | Question | Source |
|---|---|---|
| Listener 1 (Listener's opinion) | Was the disciplinary concept explained well? | Question 3 on questionnaires 1 and 3 |
| Listener 2 (Listener's opinion) | Would you be able to describe the concept confidently? | Question 4 on questionnaires 1 and 3 |
| Speaker's opinion | Self report on the accuracy and extent of knowledge transfer | Concept summary evaluated by speaker using rubrics 1 and 2 |

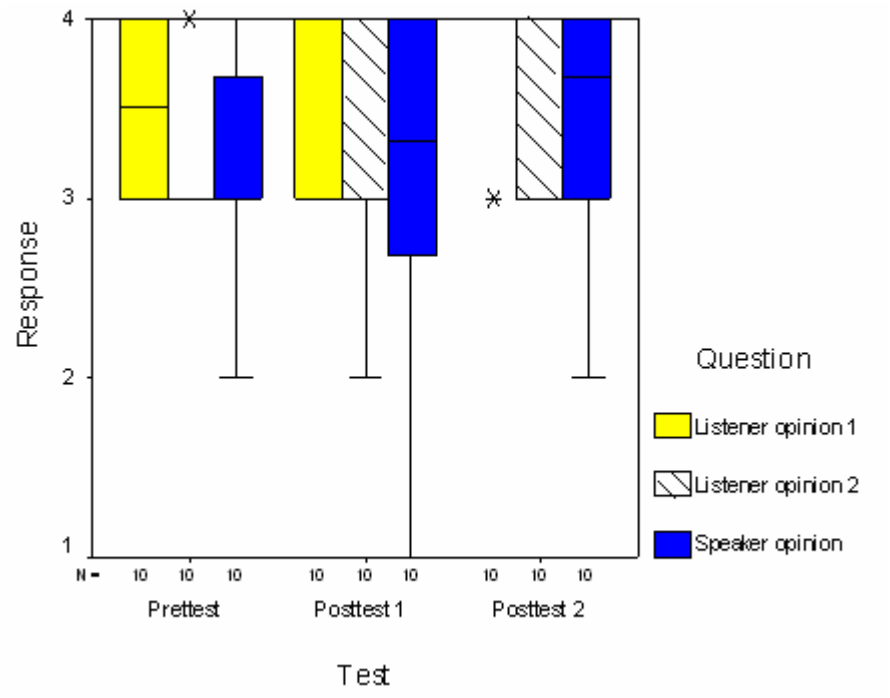



Figure 8. Comparing overall accurate knowledge transfer for three tests

From the box plot in Figure 8, all listeners agreed that they were able to explain the concept after it was explained to them (listener opinion 2). In contrast, participants tended to strongly agree that they could explain the concept confidently in posttest 2. All but one listener strongly agreed that the concept was explained well in posttest 2. More than 50% of the speakers

gave scores between 3 and 4 to the summaries written by the listeners in posttest 2. Speakers also provided lower scores of 2 in posttest 2. Further, qualitative data analysis of the explanations was performed and compared to the responses and scores given by speakers and participants. An inferential statistical analysis previously revealed a significant difference between the mean scores provided by different participants. Being a field study, participant responses were not aggregated in any further statistical analysis as participants were qualitatively different from each other.

### 4.4 Effective use of analogies and metaphors

The instruction provided on analogies and metaphors was tested for the effectiveness of their usage in the three tests. Listener and speaker perceptions of the effectiveness and usefulness of analogies and metaphors have been captured in Figure 9. This figure depicts the mean scores provided by all speakers for the posttest 1 and posttest 2. The first box in Figure 9 that provides the listeners' opinion represents the scores on question 8 of questionnaire 3. This question asks the listener if the analogies and/or metaphors used in the explanation helped him/her understand the topic better. The second box represents the scores for accurate knowledge transfer evaluated by the speaker using rubric 2. Figure 13 shows the responses for posttest 1 and posttest 2. A participant did not present his opinion of the effectiveness of analogies and metaphors used as his group member did not use any analogy in posttest 2. A follow-up with the participant revealed that she had learned the concept in a particular constrained manner which interrupted her to explain it in different perspectives. This has been explained further in Chapter 5. The analysis and potential reasons for this In Figure 12, responses strongly agree, agree, disagree and strongly disagree have been given scores of 4, 3, 2, and 1, respectively.

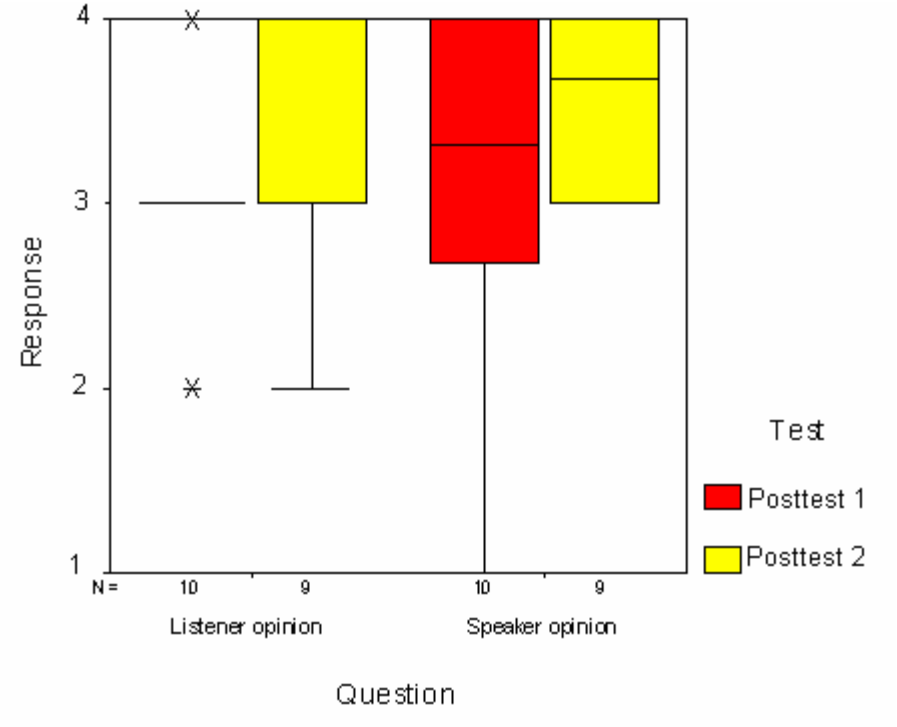



Figure 9. Comparing effective use of analogies and metaphors for two posttests

From Figure 9, it can be noted that in both the posttests, some listeners found that the analogies and/or metaphors used weren't more helpful in the explanation. However, all speakers rated their explanations with high scores in posttest 2.

### 4.5 Coefficient of correlation of responses to questionnaires

Some questions in the questionnaires were asked in different ways. The coefficient of correlation of these questions was found to reduce threats to construct validity of these questions. The coefficient of correlation for responses to these questions is provided in Table 10.

Table 10. Coefficients of correlation

| Questionnaire | Questions | Expected coefficient of correlation | Coefficient of correlation |
|---|---|---|---|
| Posttest 1 – questionnaire 3 | 8 and 9 | Divergent | -0.79 |
| Posttest 2 – questionnaire 3 | | | -0.71 |
| Follow-up questionnaire | 2 and 3 | Divergent | -0.50 |

High negative coefficients of correlation for questions 8 and 9 on questionnaire 3 indicate that these questions correctly and consistently measured whether analogies and/or metaphors were helpful in the explanation provided to them. A fair negative correlation of responses to questions 2 and 3 on the follow-up questionnaire indicate that participants were fairly correct and consistent in their responses to whether they used analogies and/or metaphors after the study was complete.

### 4.6 Within subject test comparisons

Participant responses to questionnaires were compared to their explanations for the three tests. The findings for these comparisons for each participant are provided in Table 11. The explanation transcripts for the three tests were coded for the different communication tools and their types. Table 11 relates the different communication tools used to the scores given by the speakers. Speakers evaluated the summaries written by participants on the basis of accuracy and extent of knowledge transfer. The scores provided in table 11 are the mean scores measuring accurate knowledge transfer for the three tests. Central analogies were observed to be used in the explanations and were hence coded for. When a source analog explains the principle or main points of the target concept then it is a central analogy. A non-central analogy explains and hence emphasizes on the peripheral aspects of a topic.

Table 11. Within subject response triangulations

| * | Pretest | | Posttest 1 | | Posttest 2 | |
|---|---|---|---|---|---|---|
| | **Communication tools used** | **Score (on 4)** | **Communication tools used** | **Score (on 4)** | **Communication tools used** | **Score (on 4)** |
| A | • Visual (not analogy)<br>• Listener initiated feedback | 4 | • Speaker initiated example<br>• Listener initiated feedback<br>• Superficial analogy | 3.33 | • Visual analogy<br>• Structural analogy<br>• Central analogy<br>• Extended analogy<br>• Listener initiated feedback | 4 |

| * | Pretest | | Posttest 1 | | Posttest 2 | |
|---|---|---|---|---|---|---|
| | **Communication tools used** | **Score (on 4)** | **Communication tools used** | **Score (on 4)** | **Communication tools used** | **Score (on 4)** |
| J | • Example<br>• Listener initiated feedback | 3.67 | • Superficial analogy<br>• Listener extends analogy<br>• Mildly central analogy | 3.33 | • Visual analogies<br>• Two structural analogies<br>• Extended analogies<br>• Central analogies<br>• Listener initiated feedback | 3.67 |
| Z | • Listener initiated analogy | 3.67 | • Simple, structural analogy<br>• Listener extends analogy | 4 | • Structural analogies<br>• Listener extends analogy<br>• Not central analogies<br>• Listener initiated feedback | 4 |
| L | • Visual (not analogy)<br>• Listener initiated feedback | 3.67 | • One superficial analogy<br>• Two structural analogies<br>• Not central analogies<br>• Listener initiated feedback | 3.33 | • Visual (not analogy)<br>• Simple structural analogy<br>• Not extended analogy<br>• Not central analogy | 3 |
| E | • Visual (not analogy)<br>• Listener initiated feedback | 3 | • Visuals (not analogies)<br>• Technical definitions | 2.67 | • Structural analogy<br>• Inappropriate source analog – mismatch<br>• Listener initiated feedback | 3 |
| T | • Simple structural analogy<br>• Examples<br>• Listener initiated feedback | 2 | • Speaker and listener discuss examples<br>• Speaker mentions example used by listener | 1 | • Visual analogy<br>• Structural analogy<br>• Simple and central analogy<br>• Extended analogy<br>• Listener initiated feedback | 3 |
| U | • Visual (not analogy)<br>• Listener initiated feedback | 3.67 | • Structural analogies<br>• Extended analogies<br>• Not central analogy | 3 | • Structural analogy<br>• Simple, central analogy<br>• Extended analogy | 4 |
| C | • Extends topic to concepts known to listener<br>• Listener initiated feedback | 4 | • Metaphor<br>• Concept known to listener | 4 | • Examples<br>• Structural analogy<br>• Not extended analogy | 3.67 |
| D | • Visuals (not analogies) | 2.67 | • Visual analogy<br>• Structural analogy | 2.33 | • Technical definitions<br>• Visuals (not | 3.67 |

| * | Pretest | | Posttest 1 | | Posttest 2 | |
|---|---|---|---|---|---|---|
| | **Communication tools used** | **Score (on 4)** | **Communication tools used** | **Score (on 4)** | **Communication tools used** | **Score (on 4)** |
| | • Formulae<br>• Speaker prompted feedback | | • Simple, central analogy<br>• Extended analogy<br>• Speaker prompted feedback | | analogies)<br>• Formulae<br>• Listener initiated feedback | |
| B | • Visuals (not analogies)<br>• Listener initiated feedback | 3 | • Visual analogy<br>• Structural analogy<br>• Simple, central analogy<br>• Extended analogy<br>• Listener initiated feedback | 4 | • Visual analogy<br>• Structural analogy<br>• Complex, central analogy<br>• Extended analogy<br>• Listener initiated feedback | 4 |

Key

* - Participant

U - Central analogies corresponding to high scores

U - Non-central analogies corresponding to low scores

The overall scores given by speakers on summaries written by listeners, increased through posttest 2. It was also observed that 70% of participants used structural analogies and extended them in the posttests. Fifty percent of participants made visual analogies in either or both of the posttests. There were 6 explanations where the usage of 'central' analogies corresponds to relatively higher scores within participants. These explanations have been underlined in Table 11. There were 3 instances where the usage of 'non-central' analogies corresponds to relatively lower scores within participants. These explanations have been highlighted in Table 11. These results may highlight characteristics of effective analogies and metaphors which are described in Chapter 5.

There were two explanations that were outliers where communication tools used did not correspond to responses expected. Participant D used structural, central, and visual analogy to explain her concept in posttest 1, yet the score obtained on the summary provided by the listener was relatively lower. Another outlier was the posttest 2 score for participant Z. In his explanation, participant Z used structural, extended, and non-central analogies. The score obtained through the usage of non-central analogies was consistently high as compared to posttest 1. The study being a field study has many other confounding variables and the explanation for these outliers lies within the purview of the limitations of the study.

### 4.7 Responses received after completion of study

After the instruction was provided to participants and the study was complete, participants were revisited to determine if the communication tools taught were of any practical value to them. Participant feedback was solicited via the follow-up questionnaire (refer to Appendix B). This provided a rich source of data regarding the application and usage of analogies and metaphors by the participants after the instruction was given hence highlighting the effect of the instruction. Figure 10 provides a box plot of the responses of the participants for the three questions 1, 2 and 3 on the follow-up questionnaire. Question 1 asked participants if they noticed analogies and/or metaphors in their communication since the study was over. Question 2 asked participants if they used analogies and/or metaphors in their communication since the study was over. Question 3 of the follow up questionnaire also demanded the same information as question 2 but was worded differently.

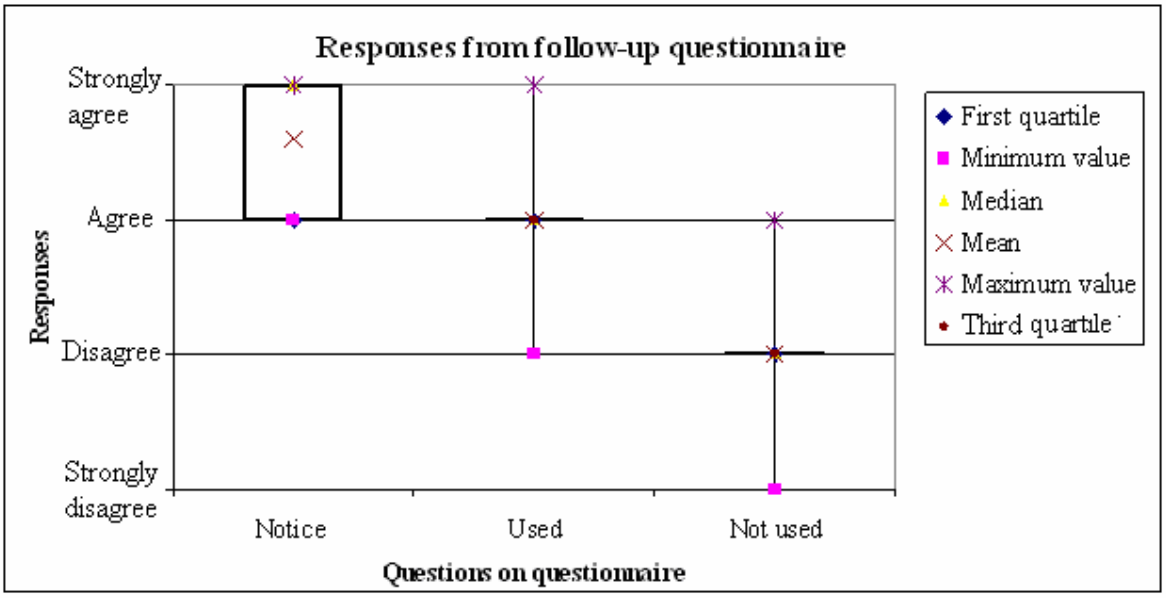



Figure 10. Depicting use of communication tools after study is complete

As seen in Figure 10, all participants believe that they notice and recognize analogies and metaphors whenever they hear and read them. More than 50% of the participants agreed that they used analogies and/or metaphors after the study was over. Question 5(b) on the follow-up questionnaire asked participants if they considered analogies and metaphors to be useful communication tools when communicating with people from different backgrounds. All participants agreed that analogies and metaphors can be useful in communicating with people from different backgrounds.

Further, observations of participants after the study revealed that participants used metaphors and structural analogies in the different modes of communication. These field observations were taken from a week after the study was over for more than a month in class and group meetings. Participants were observed creating analogies and metaphors and extending then in their interaction. Table 12 enlists some of the analogies and metaphors used by participants in meetings, presentations, and project reports after the study was over.

Table 12. Observations of participants after study was over

| Analogy/Metaphor | Usage | Type of interaction |
|---|---|---|
| Analogy | J says "the iron mesh in the water filter is kind of like you put a coffee filter in the coffee pot" | Replying to question about water filter design during team presentation |
| Metaphor | J says "harvest parts for my computer on ebay to rebuild my computer" | Team meeting where J explains that she couldn't come for the previous meeting because her laptop is broken |
| Metaphor | T writes "arsenic is the most poisonous species" | T describes the effect of arsenic in drinking water in final project report draft |
| Analogy | T explains "the sand and iron in the filter would be like a cartridge where you take out the layer that is used"<br>A adds "like a bean bag" | T and A in a team technical meeting with faculty member explain the design of sand and iron in the sand type water filter |
| Metaphor | A says "cartridges of ceramics" | When discussing the two water filter designs, A uses the "cartridge" analogy created by T to continue with the discussion in the group technical meeting. She explains the ceramic type filter this time. |
| Metaphor | J says "the problem of making ceramics is we will need a recipe of sorts"<br>A replies "there are a whole bunch of ceramic people there, aren't they going to help us with the recipe?" | Group members brainstorm in group meeting |

Although inferential statistics depicted that there was no significant difference in the accuracy and extent of knowledge transfer, results from a within-subject qualitative data analysis, responses of follow-up questionnaire and field observations of participants after the study was complete, illustrate that the instructional tool may be of practical importance in teaching the use of effective analogies and metaphors to enhance communication.

# Chapter 5. Discussion

The responses from self reports and within-subject qualitative data analysis reveal that participants used structural analogies and extended them in the posttests. Since common structures and partial structures promote knowledge transfer, structural analogies that focus on highlighting and drawing correspondences between the structural features of two analogs can enhance understanding and learning (Blanchette & Dunbar, 2000; Bonnardel & Marcméche, 2004; Dunbar, 2001; Gentner, 2003, 2004; Loewenstein, 1999; Novick, 1988; Thompson et al., 2000). Structural analogies that are extended by drawing explicit correspondences between the analogs may lead to positive analogical transfer (Novick, 1988). These analogies draw on previously learned knowledge. Connecting new knowledge to prior knowledge can initiate processes of meaningful learning and elaboration hence facilitating understanding and long-term memory storage (Ormrod, 2004).

In this study, beyond teaching the use of effective analogies and metaphors, trends were observed in the kinds of analogies used and their effects on communication. The usage of analogies by participants evolved from using superficial to structural analogies. For example, participant A used a superficial analogy in posttest 1 and used a structural analogy with a visual analogy in posttest 2. An excerpt of the transcript of explanation given by participant A (speaker) to participant J (listener) in posttest 1 is as follows:

> A – so basically /?/ very complicated formulas that will tell you for each food material you have ..what type of material../?/ plastic, glass what /?/ bacteria there are..
>
> J –okay

A – main thing I wanted to show you about this /?/ highlights what products are best for coming into food products. So yogurt, you could use a /?/, use a bottle or /earthenware/ pot, and there are also several grades of plastic. /?/ cancer /?/

J – hmm…that's kind of bad

A – ya../?/

J – so how do they figure out which is which..what do they consider?

A – hmm..that is..

*L prompts A to use analogies and/or metaphors*

A - ..alright..our food processing tables are similar to our water filtration /table../ /?/ what materials would be best to use

In the above transcript, participant A explained the food packaging processes. In order to explain this concept, participant A provided examples. The listener initiated feedback and confirmed her interpretation. When prompted to use an analogy and/or metaphor, the speaker compared a table used to select the food packaging material, to a table used in the group project familiar to the listener. In doing so, the speaker used a superficial analogy. The speaker tried to draw a comparison between the source and target analog by saying that the two tables were essentially for the same function. She also highlighted a peripheral aspect of the topic by providing an analogy for food processing tables instead of food packaging processes. In response to the explanation provided, the listener provided the following feedback on questionnaire 3:

Question 6. He/she explained the concept better this time than last time? *Disagree*

Question 8. The analogies and/or metaphors used in the explanation helped me understand the topic better. *Disagree*

The listener provided a summary of the topic explained to her in questionnaire 2. This summary was evaluated by the speaker using rubrics to measure the extent of accuracy and knowledge transfer. The mean score for the evaluation was 3.67.

The same speaker used a structural analogy in posttest 2 as compared to a superficial analogy in posttest 1. The transcript of the explanation by participant A in posttest 2 is as follows:

A - /?/ /use an analogy and so I'm considering the use of consuming sugar in producing alcohol..

J – okay

A - /comparing the fermentation process/ to the human digestive system ../?/ and considering all the chemical compounds used ../?/ /?/ /?/

*A points to a diagram comparing the fermentation and digestive process*

J – there's an intestine in the bottle? That's cool! I like the intestine in the bottle…

*Both J and A laugh*

A - /?/ example gas../?/ /?/ wines.. /?/ red wines /?/

*J's tone seems as though she were asking a question but her voice is inaudible*

A - /I figure that wines can be /?/

In the above transcript, the speaker compared the digestive system's functioning to the process of fermentation. She then drew correspondences between the chemical compounds in both cases. The speaker also explained using examples. To complement her explanation, the speaker created a visual which explains the fermentation process in terms of the digestive process. This visual analogy has been presented in Figure 14. Positive knowledge transfer was observed when participants extended analogies by drawing correspondences and making visual

analogies. Visual analogies made the process of drawing correspondences more explicit and facilitated elaboration. When the speaker (participant A) presented the visual analogy, the listener remarked on it "there is an intestine in the bottle? That's cool! I like the intestine in the bottle." These remarks illustrate that the listener did process the analogy and correspondences presented in the visual analogy. The visual analogy used by the speaker in posttest 2 is presented in Figure 11.

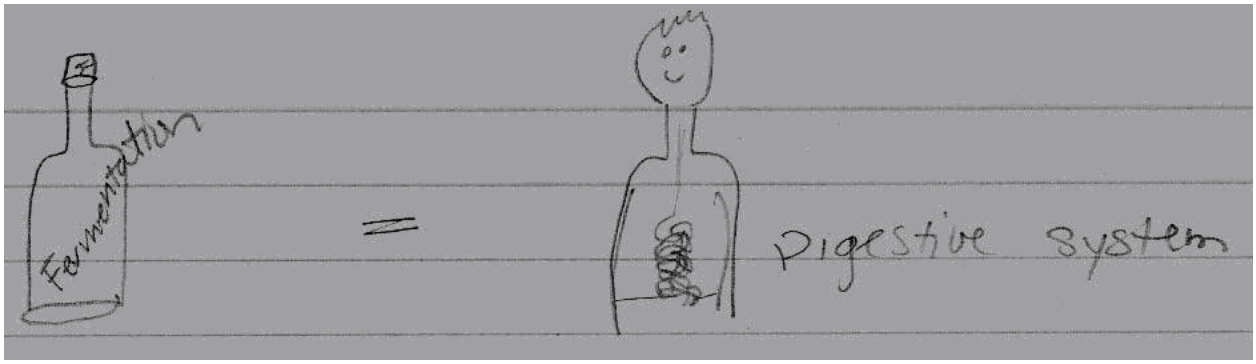



Figure 11. Visual analogy used by participant A in posttest 2

In using the digestive process to explain the fermentation process, the speaker highlighted the main principle of the fermentation process, which is the conversion of larger components to smaller ones with chemical reactions. This is hence a central analogy. This may also be considered a structural analogy because the underlying principle behind the two analogs is the same. As a response to this explanation, the listener gave the following feedback on questionnaire 3:

Question 6. He/she explained the concept better this time than last time? *Agree*

Question 8. The analogies and/or metaphors used in the explanation helped me understand the topic better. *Strongly agree*

Triangulating the listener's feedback with the speaker's evaluation of the listener's summary, the mean score provided by the speaker was 4, which is relatively higher than that obtained in posttest 1.

The results from the study suggest that the selection of the source analog influenced the effectiveness of the analogy in an interdisciplinary group even when it was a structural and extended analogy. It was observed that if the source analog highlighted the peripheral aspects of the concept to be explained, there was negative knowledge transfer. An effective analogy had a *central* source analog that emphasized the main points or principle of the concept being explained.

The interruptive feature of non central analogs has been depicted using the explanation provided by participant E (speaker) to participant T (listener) in posttest 2. The following is an excerpt from the transcription of the explanation provided by participant E in posttest 2 on stagnant water and malaria:

> E – and the stagnant water can be dangerous for drinking because it provides a better incubator for many kinds of bacteria and other parasites like when the water is standing you will have mosquitoes..you will have bacteria..you will have viruses..you will have all kinds of /?/..
>
> T – does the malaria start with the mosquito or does it ..
>
> E – start with the mosquito..malaria is spread by mosquitoes..

In the above transcript, participant E explained how stagnant water is the cause of growth of malaria-carrying mosquitoes. The main point that the speaker intended to highlight was that mosquitoes are not the cause but carriers of infection and these malaria-carrying mosquitoes grow in stagnant water. The speaker used a simple analogy comparing stagnant water to an

incubator for malaria. The listener then asked the speaker if the "malaria starts with the mosquito". In this case the analogy of comparing stagnant water to an incubator is not a central analogy because it highlights a peripheral concept and not the main point of the explanation. Here, inaccurate knowledge transfer was observed when the listener asks the speaker if "malaria starts with the mosquitoes or..". The speaker is trying to clarify the main point of the explanation – whether mosquitoes are malaria-causing or malaria-carrying.

Triangulating the findings from the transcripts to the feedback provided by the listener, the listener gave the following feedback on questionnaire 3:

Question 8. The analogies and/or metaphors used in the explanation helped me understand the topic better. *Disagree*

Further triangulating the listener's feedback with the speaker's evaluation of the listener's summary, the mean score provided by the speaker was 3 which was the same as that obtained in the pretest.

A central source analog may or may not be simple to improve explanation. In a certain explanation, the analogy was structured, extended, visual, and central but the source analog was complex, which interrupted knowledge transfer. Complex analogs may be defined as prior knowledge in which more than one event corresponds to an element in the target analog. Hence when a complex source analog is used, the mapping between the two analogs may not be clear. In such a case, understanding the source analog may overshadow the process of understanding the target analog.

The following excerpt of the explanation by participant B presents a structured, extended, visual, and central but complex source analog:

B – ya like mix that and then break them down in like smallest components..and you do this so you can analyze each step..to like improve the efficiency and know exactly whats going on and everything..and its similar to like if you think about mouse trap ..get every like the whole big grid and everything..you have one goal to like catch the mouse and this you usually have one goal..usually like get ethanol from corn at the beginning of the /beanstock/ and then you start there like a ball goes through and you knock everything down and you finally catch a mouse..and you have small operations down it..like the ball goes down to the spring board will be one operation ..like grinding could be operation /?/ and all these end up in something else in like chain reaction..

In the above explanation the speaker explained the topic unit operations. The principle of unit operations is that the complete job is broken into smaller tasks and operations and it is necessary to ensure high efficiency of each unit operation to improve the efficiency of the overall job. To explain this concept, the speaker compared the method of unit operations to the working of a mouse trap. Like in a mouse trap each operation must take place correctly to trap the mouse, similarly in unit operations the efficiency of each unit counts. The speaker used a structural, central, visual analogy; however the source analog – the process of catching a mouse using a mouse trap - did not draw one-on-one correspondences to the source analog. Even though the speaker extended the structural analogy by drawing overall comparisons between the two analogs, there was no one-on-one comparison. A possible solution to using complex source analogs may be by making a visual analogy to elucidate the one-on-one correspondence between the analogs. The visual created by the speaker did not provide a clear one-on-one comparison between the two analogs. This visual is presented in Figure 12.

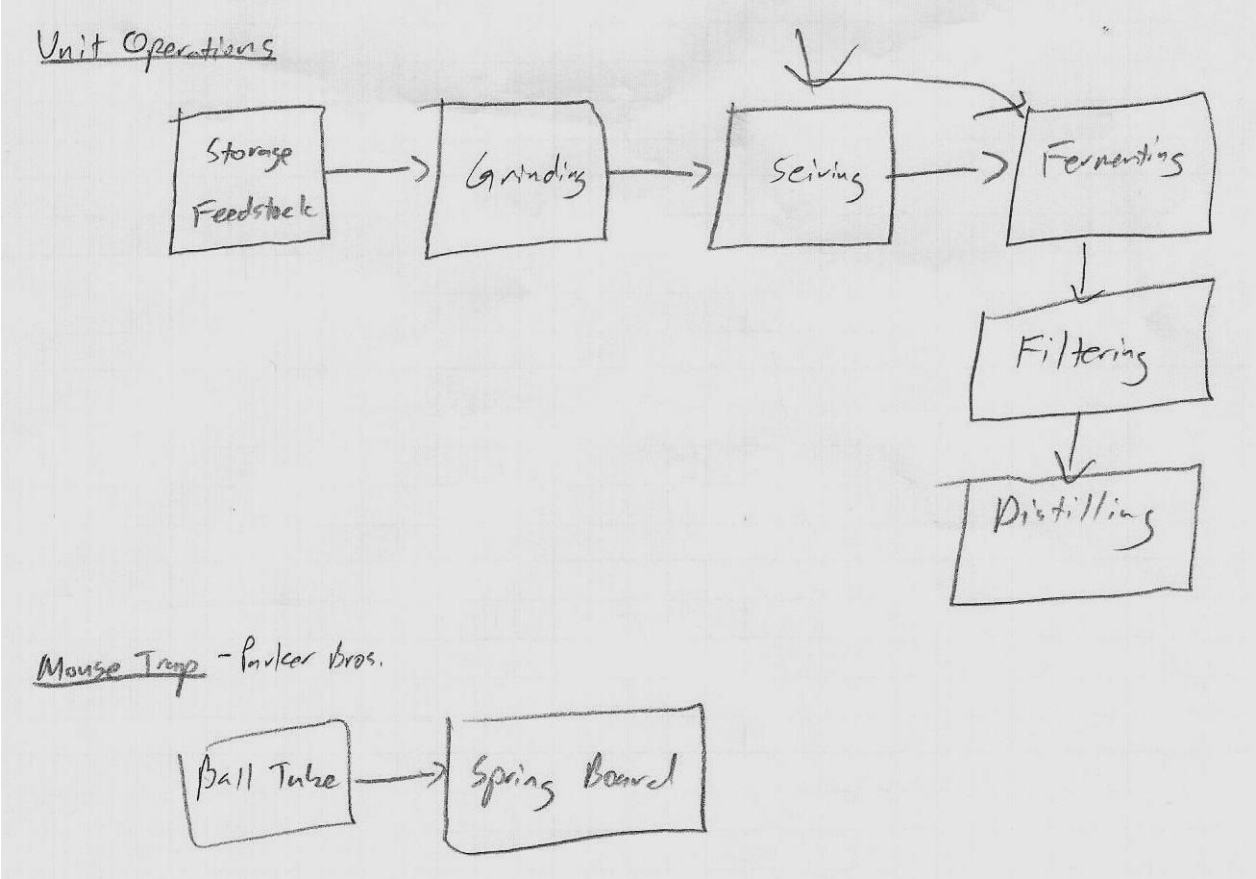



Figure 12. Visual analogy used by participant B in posttest 2

Most participants also drew visual analogies as they progressed through the instruction. This instruction may be a good teaching tool for visual analogies.

An effective analogy therefore is structural, extended, central, simple and visual for the purpose of explaining disciplinary concepts in interdisciplinary groups. Participant T (speaker) presented an effective analogy in her explanation in posttest 2. The following is an excerpt from the explanation to participant E (listener):

T – okay..growing a business is like growing a tree ..because first you start with the seed right..

E – okay ..

T – that's like one idea..one product whatever..and its made by the entrepreneur..He is like the main person ..he like thought of it..he is like we will /?/..so the seed has to grow right? ..so you need water nutrients and stuff ..you know you need stuff to go into it..let me make a tree..*(T draws a tree)*..thats where finances come in..so we have finances putting money ..like money is like nutrients..to make it grow because nothing will happen if you don't have any money..

E – uhmm..

T – so it starts to grow and its like going to grow into a tree…so a tree must have a structure to it..right..and needs like a trunk to hold it up..like main body and that's going to be managers..managers..thats like main part of it..and then whatever tree like you know starts to grow branches..its gets real specialized and big and gets all complicated and specialized and what not..and that's going to be like production and manufacturing ..and stuff like that and so and then once you know the tree has all branches and stuff and it gets big enough ..then it starts to have like flowers..

E – did you say ..convention or what did you say production..

T – production..ya..production and manufacturing..

E – okay

T – and you know..its like making the tree grow..

E – right..

T – producing all these branches and leaves and stuff and so you know after a while..

E – uhmm..

T – after a while the tree starts to grow flowers and whatever for it to..producing all these branches and leaves and stuff and so you know like and that like really pretty flowers and

that's like marketing!..you know we are trying to get all the /customers/ to come..check it out..and check the tree out for pollinating the tree..and so that's like advertising and sales and you know like people look at the tree and say ..oh the tree is like really pretty..

The speaker (participant T) intended to explain the contents of a business plan which include the different aspects that are involved in growing a business. The speaker explained this concept by comparing the process of growing a business to growing a tree (source analog). In doing so, the speaker used a structural, extended, central, simple, and visual analogy. She presented many one-on-one correspondences between the elements of the source and target analog. She compared the seed to an entrepreneur who like the seed has the idea that has the potential to grow into a business; the branches to the different departments that ensure specialization and expertise; the trunk of the tree that holds the weight and supports these branches to the management that control and support the organizational functioning; water and nutrients to finance for growth and expansion of the business; and flowers to the marketing department that attract customers to the organization. These correspondences are explicitly depicted in the visual analogy presented by the speaker. This visual analogy is depicted in Figure 13. The various pieces that are involved in growing a business is the main point intended to be communicated by the speaker, which is well covered by the analogy. This is hence a central analogy as well. Further, the source analog – growing a tree is a well known concept, which makes the analogy a simple analogy.

Triangulating the findings from the explanation transcripts with the feedback presented by the speaker are the responses presented by the speaker to questions 7, and 8 on questionnaire 3:

Question 7: When you think about the topic now, do you think of any of the analogies and/or metaphors used to explain it? *Yes*

Question 8. The analogies and/or metaphors used in the explanation helped me understand the topic better. *Strongly agree*

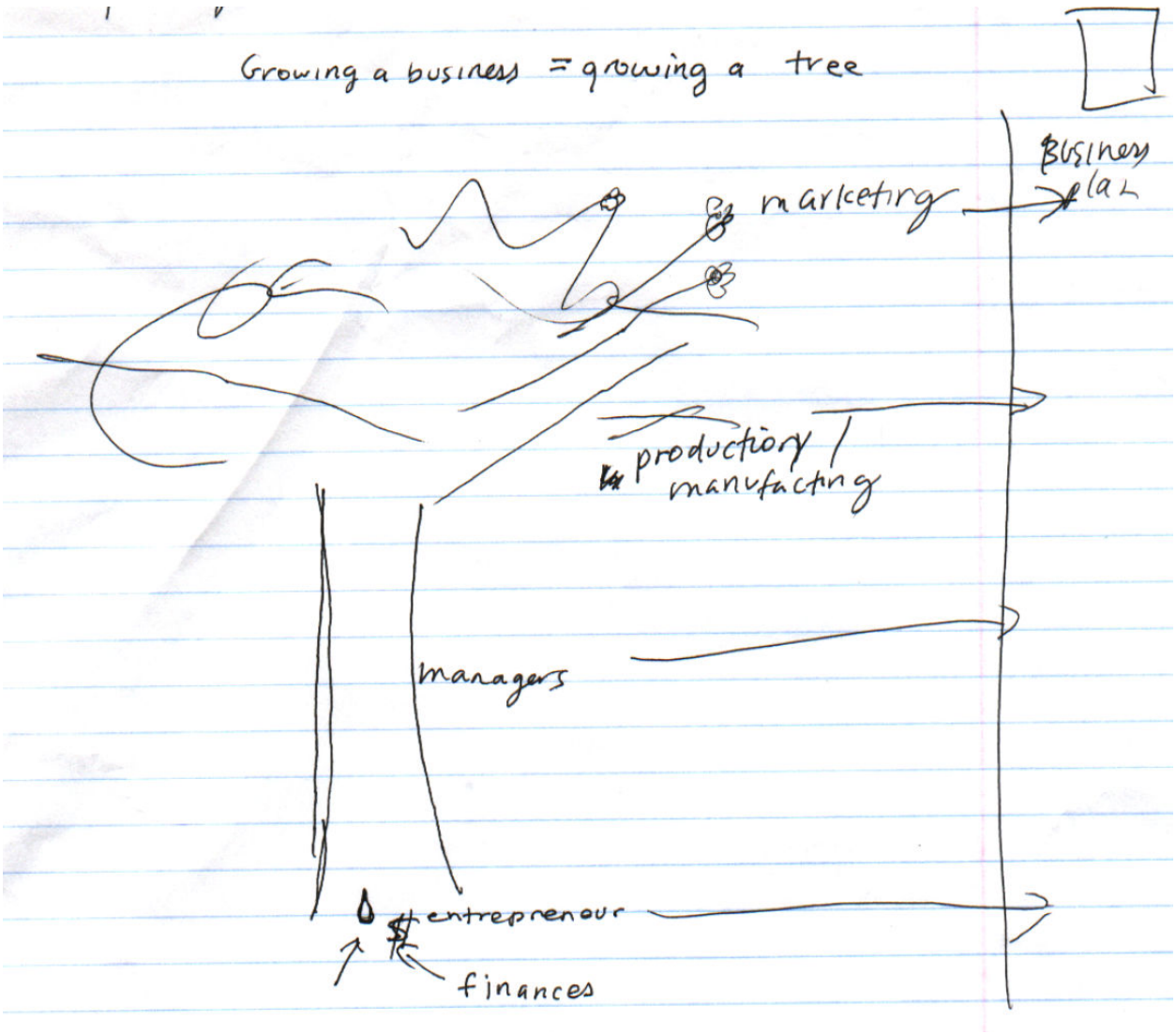



Figure 13. Visual analogy used by participant T in posttest 2

Further triangulating the responses obtained with the score given by the speaker to the summary written by the listener, the speaker assigns a score of 3. This score was higher than the mean scores of 2 and 1 assigned on the pretest and posttest 1 respectively.

In developing an instructional tool to teach the generation of effective analogies and metaphors in interdisciplinary interactions, activities were included that elaborate the procedure of selecting a simple and central source analog, highlighting the structural features and drawing correspondences between the analogs to extend the analogy. Generating analogies may require practice, which may be required apart from the activities in the instruction depending on the students.

There were a few cases in the study when participants did not use analogies to explain their topics even though they had done so before. After following up with the participants in these cases it was revealed that certain topics were taught in a very technical fashion and are ingrained as those structures in their minds. It was difficult for these participants to explain or think about these topics in any other manner. This may be a case when prior knowledge constrains divergent thinking (Smith, Paulus, & Nijstad, 2003). Analogies are known to combine partial structures of knowledge which may be parallel to the cognitive process of creativity (Baughman & Mumford, 1995; Hee Kim, 2006; Holyoak, 2005; Mumford, Baughman, Maher, Costanza, & Supinski, 1997; Mumford, Baughman, Threlfall, & Supinski, 1996; Mumford, Marks, Connelly, Zaccaro, & Johnson, 1998).

Only a few participants used metaphors in their explanations during the tests. The usage of metaphors was observed to be higher after the study.

A supplementary study was conducted where disciplinary project teams were observed for the usage of analogies and metaphors when they presented their project reviews in a time of 6 minutes in a board room setting. Senior Industrial and Systems Engineering project teams presented their projects to a faculty member with no prior knowledge about these projects in an elimination-type board room setting. The team members were hence given the task of

condensing their project details to be presented in less than 6 minutes to someone new to project concepts. Essentially, this setting is similar to a cross-disciplinary or cross-functional setting where it is necessary to effectively communicate new ideas. Six out of twenty teams used analogies and/or metaphors in their discussions, one presented a visual analogy. These teams were not provided the instruction. It was observed that three of the six teams used analogies to explain their design. Analogies used to explain the design were 'muffin-pan' like design, and project like a 'lego-building'. In line with the concept of culturally influenced metaphors, some such metaphors were 'fixing of cosmetics on the excel-based tool', 'attack our second goal', and 'strike that problem'. Verbal metaphors were not used to describe designs. It was interesting to note that analogies were used to describe designs which are generally depicted by visuals. An interview with a participant who presented a metaphor revealed that he read a lot of management and communication books and is interested in human psychology. He described himself as a 'different' engineer and an 'outgoing' one. Aligning with the findings from the tests, an examination of the influence of ones 'open' and 'creative' personality on their usage of analogies and/or metaphors may be a prospective study.

From the two studies conducted, it was observed that analogies were used in explaining designs. Further, numerous visual analogies were used. Considering the digitization of communication, it may be easier to make visuals and animations. This may facilitate the use of visual analogies and metaphors.

## 5.1 Limitations of study

The study was a field study which has its advantages and disadvantages. The instructional tool was tested in a class setting (which was a natural setting). Performing a field study reduced the threat of modified behaviors and increased the generalizability of the instructional tool

created. This also informed the study about the other factors that may influence the effect of the instruction apart from its content effectiveness, for example, motivation to learn group communication. A field study prevented the control of confounding factors that distorted the results of the statistical analysis. Participants were free to select the disciplinary topics they would explain. These topics, being different for every participant, may have varying levels of complexity. Expertise and prior knowledge may have influenced the understanding of these topics during the explanations.

It was observed that a few participants were not motivated to participate in the study. An instruction is more likely to be successful if the students taking the instruction are motivated to learn the concept. Activities or scenarios that establish the significance of communication across disciplines should have been included prior to this instruction. These were included in the refined instructional tool.

The sample size for the study was small (n = 10), with two participants in each interdisciplinary group. A larger sample size would provide results more representative of the general population of interdisciplinary groups. Further, a larger sample size and a controlled experiment would yield undistorted results in the statistical analysis. The Likert-type scale used on the questionnaires for the study had 4 rating categories. This forced participants to either agree or disagree, but having lesser number of rating categories reduced the discriminative power of which the raters were capable. For the purpose of this study seven rating categories may be difficult for raters to analyze, but six rating categories may increase the reliability of the scale and may not go beyond the rater's limited powers of discrimination (Matell & Jacoby, 1971).

The effects of the tests on the instruction could not be measured using comparable control groups. Finding comparable interdisciplinary groups involves matching the group disciplinary

composition, group interaction, group member attitudes, and other factors (Bushe & Coetzer, 2007). The effects of the instructional tool were confirmed through a follow-up feedback from the participants that would give an insight into the practical value of the communication tools taught independent of the tests.

This study does not differentiate between visual analogies and metaphors. The study defines visual analogies and accommodates their observations in the results. This may have concealed valuable information about visual metaphors as helpful or interruptive communication tools in interdisciplinary and cross-functional settings.

### 5.2 Refined instructional tool

The study tested the effectiveness of the instructional tool on communication between group members from different disciplines. The instructional tool was designed on the basis of various pedagogical theories. After the study was over, the instructional tool was refined on the basis of:

1. Feedback received from students regarding the contents in the study that were helpful and improvements that could be made to the tool – Students provided their inputs on the activities that were helpful to them and those that could be condensed. The refined instructional tool is designed to make a concise, effective compilation of instruction and activities.
2. Limitations observed in the study – The instructional tool was refined to reduce the limitations that were observed in the tool during the study. The refined study includes scenarios given to students that expose them to situations of cross disciplinary communication of high significance. This is intended to motivate students to learn the communication tools in the desired context.

3. Characteristics of effective analogies that correspond to accurate knowledge transfer across disciplines – It was ensured that activities which provide practice in creating structural, extended, central, simple and visual analogies are included in the instructional tool.

   The refined instructional tool is provided in Appendix A.

## 5.3 Guidelines for interdisciplinary and cross-functional group communication

Analogies and metaphors employ previous knowledge to communicate new concepts. Group members from different disciplines and hence different terminologies, consolidate their shared mental model by communicating each other's disciplinary knowledge that plays a role in the group functioning (Burke et al., 2004; Bushe & Coetzer, 2007; Cannon-Bowers & Salas, 2001; Cannon-Bowers, 1990; Salas, 1992). Previous research suggests that the use of structural and extended analogies facilitates learning (Gentner, 2001, 2003, 2004; Gentner & Markman, 1997; Holyoak, 2005; Novick, 1988; Ormrod, 2004; Shalley, 1995). Metaphors blend known knowledge structures to create emergent meanings (Cornelissen, 2005; Cornelissen et al., 2005; Lakoff, 1993; Lakoff & Johnson, 1980).

Findings from this study reveal that central, simple and visual analogies are also characteristics of effective analogies that may be helpful in communicating disciplinary specific knowledge in interdisciplinary groups. Central analogies highlight the main points or principle of the topic being explained. Simple analogies involve source analogs which are known to the audience. In interdisciplinary and cross-functional groups, topics from the disciplines and functions of the audience, in which the audience is expert, would make simple source analogs. In situations where an audience of varied disciplines must be addressed, a simple source analog

must be commonly known. Visual analogies draw explicit correspondences between the source and target analog, which further facilitate effective communication.

An in-depth qualitative data analysis in the study also revealed that analogies and metaphors are suitable in communicating general ideas about an unknown topic. This reinforces results from previous research which states that no two concepts are alike and hence analogies and metaphors may be used only in general descriptions. Deeper analysis and iterations of correspondences between the analogs may reveal discrepancies between the analogs and hence lead to inaccurate knowledge transfer.

# Chapter 6. Conclusion

This study primarily focused on developing an instructional tool to teach analogies and metaphors for effective communication across disciplines and functions, tested the effectiveness of this tool, and refined it. The results of the tests and feedback obtained during and after the study, demonstrate increased and effective application of communication tools taught in an interdisciplinary setting.

This study may contribute to educational and group communication research in the following ways:

1. Providing a usable instructional tool to enhance cross-disciplinary and cross-functional group communication. This instructional tool may be used as (1) may be used as an instruction in class, in the form of a presentation with interdisciplinary student groups; (2) may be adapted to an online instruction with facilitated group activities in class and virtual organizational settings.
2. Testing the use of analogies and metaphors in interdisciplinary settings to identify characteristics of effective and ineffective analogies – Effective analogies were defined as those that correspond to accurate and substantial knowledge transfer and understanding in communication. Analogies that correspond to substantial knowledge transfer have structural similarities and draw explicit comparisons between the source and target analog (Blanchette & Dunbar, 2000; Bonnardel & Marcméche, 2004; Dunbar, 2001; Gentner, 2003, 2004; Loewenstein, 1999; Novick, 1988; Thompson et al., 2000). By measuring knowledge transfer in an interdisciplinary group context using analogies, it was observed that selection of a simple and 'central' source analog is essential for accurate knowledge transfer. The principle or main points of the

concept to be explained must be emphasized using analogies. Using analogies for peripheral aspects of a concept obscures the principle concept and may misalign the intent of the communication.

3. Results suggesting enhanced communication using analogies and metaphors may validate previous findings of the potential advantages of using them as communication tools.
4. Presenting prospective research questions for future research concerning analogies, metaphors, disciplinary and interdisciplinary teaching and learning, and group communication.

## 6.1 Future Research

The study has unearthed some possible characteristics of effective analogies in interdisciplinary group settings. Central analogies were identified as a characteristic of effective analogies in this study. Future studies may validate these findings using larger sample sizes. This instructional tool has been developed for communication between individuals from different knowledge backgrounds. Analogies and metaphors may be further examined as 'common generic-spaces' between disciplinary and function-specific mental models. Further research may explore the relation between the usage of these communication tools in teams and the consolidation of shared mental models in teams.

This tool was tested without a control group. Future studies may test the tool with an equivalent group to eliminate any effect of the tests on the effectiveness of communication. Considering a non-equivalent control group could introduce other confounding variables in the study, hence the suggestion of a comparable control group.

Comparing the creativity of participants using effective and ineffective analogies and metaphors may highlight how analogies and metaphors parallel the cognitive process of creativity. The structure-mapping theory for analogies and domains interaction model of metaphors discuss the mapping and combining of knowledge structures for various cognitive activities (Blanchette & Dunbar, 2000, 2001; Cornelissen, 2005; Cornelissen et al., 2005; Dunbar, 2001; Gentner, 2001, 2003, 2004; Gentner & Markman, 1997; Holyoak, 1984, 2005; Novick, 1988; Oswick et al., 2002; Tourangeau, 1991, 1982). The cognitive process for creativity also emphasizes reorganization and recombination of known ideas from different domains to devise novel solutions (Baughman & Mumford, 1995; Mumford et al., 1997; Mumford et al., 1996; Mumford et al., 1998; Runco, Dow, & Smith, 2006; Shalley, 1995).

This study was conducted in an interdisciplinary context. During the study, it was observed that the ability to use and understand analogies and metaphors varied depending on the disciplinary background of the participant. It was observed that participants from certain disciplines like marketing looked at concept from different perspectives and used analogies more effectively. Following this research to shortlist some of these disciplines and studying their underlying teaching methods may reveal common teaching methods that facilitate this recombination of ideas.

It was observed during the study that a substantial number of participants used visual analogies. Observations and discussions with experienced American Sign Language (ASL) users indicated that it is easier to communicate using analogies and metaphors in sign language. ASL users reasoned that analogies and metaphors are more visual and it is hence easier for them to symbolize the picture instead of spelling the letters in words one at a time. The results of this study revealed that many participants drew visual analogies even when they were not prompted

to do so. Previous research also suggests that a sizable portion of college students are visual learners (Adkins & Brown-Syed, 2002; Clarke, Flaherty, & Yankey, 2006; Morrison, Sweeney, & Heffernan, 2003). Future studies examining the visual nature of analogies and metaphors may hence propose that analogies and metaphors are good instructional tools because they include the verbal and visual component.

The instructional tool from this study may be further consolidated in terms of the number of topics, to develop an online communication toolbox. This toolbox may support virtual interdisciplinary and cross-functional collaborators with effective alternative communication tools.

Future studies may examine the correlation between source analog characteristics, cognitive demands and communication efficiency, possibly identifying characteristics of analogies and metaphors in demanding situations. This may further reinforce analogies and metaphors as instructional media.

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# Appendix A

**Communicating with people from different disciplines and functions**

Team members need to communicate for effective team communication. Have you been in a group or team where you have had to explain, convince or brainstorm with someone from a different discipline or area of expertise?

Since the terminologies used by people from different disciplines are diverse, how would you communicate effectively to be on the same page?

**Analogies**

Analogies help understand newer concepts by mapping information from prior knowledge. For example, electrons revolve around the nucleus in an atom like planets revolve around the sun in our solar system. Here, knowledge of the relationship between planets and the sun is mapped onto the interaction between electrons and nucleus to understand the dynamics of the atomic structure.

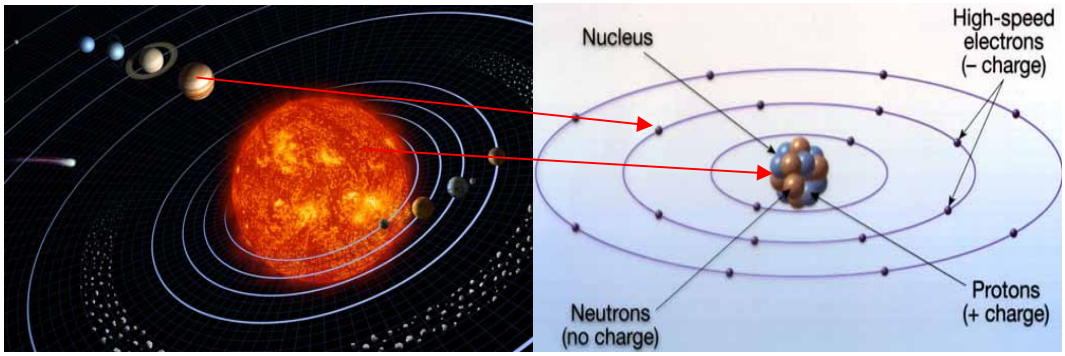


Figure 1. The planetary model of atomic structure

The above diagram is a visual analogy which makes explicit correspondences between the solar system and the atomic structure. The known concept from which knowledge is mapped is generally known as the source analog and the unknown concept onto which information is mapped is the target analog.

Analogical mapping is known to dominate our daily cognitive activities such as reasoning and encoding information onto our long term memory (Dunbar, 2001; Holyoak, 2005; Ormrod, 2004; Oswick et al., 2002). Analogies have been used in teaching and in design.

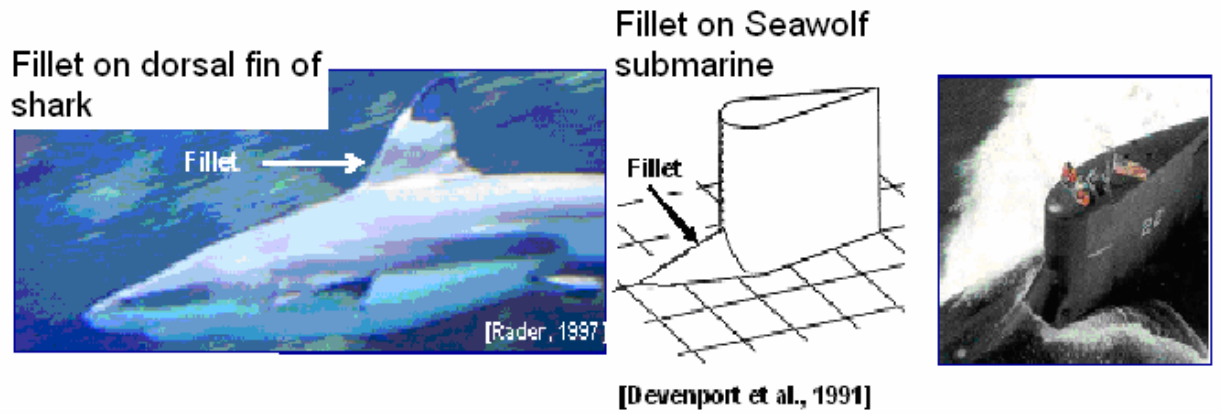


Figure 2. Design concept borrowed from sharks – fillet on the dorsal fin (Alley, 2007)

The above figure is a visual analogy where the source analog is shape of a shark's dorsal fin and target analog is the design of the submarine. The hydrodynamic characteristics of the submarine are enhanced by mapping the idea of having a fillet as observed in sharks.

**Group activity 1**

You are given three stories and a question. Read the three stories and then the question. Find a solution to the question in your group. The clues to solving the question are in one of the three stories.

The three stories from Gick and Holyoak (1980), pg 353-354:

1. <u>The Attack-Dispersion story</u>

A small country was ruled (from a strong fortress) by a king. The fortress was situated in the middle of the country surrounded by farms and villages. Many roads radiated outward from the fortress like spokes of a wheel. 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. However, the general learned that the king 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 king 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 and render it impassable, but it would also destroy many neighboring villages. It therefore seemed impossible to mount a full-scale direct attack on the fortress. 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. Each group continued down its road to the fortress so that the entire army finally arrived together at the fortress at the same time. The fortress fell and the king was forced to flee into exile.

2. The wine merchants

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 sent out for the duke's palace at once. An hour before sundown they came to a place where the bridge had been washed down 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. Te cart overturned, and the horses, the wine, and the driver were washed away.

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.

3. The identical twins

Once there were identical twins that 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 where 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.

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 broadjumping event. The race began and the students rushed into the woods. The twin rushed into the woods and waited until the others had 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 the event.

The question

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 a 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. 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 ray may be broken into rays of smaller intensity approaching from different directions simultaneously at the center to create a higher intensity ray. This would destroy the tumor.

**How did you arrive at this solution – cognitive process of creating and understanding analogies**

While solving the problem did you think that any of the three stories given above had similarities to this problem? Which one?

Attack-dispersion story. Hence the source analog was the attack-dispersion story and the target analog was the question. What are the similarities between the story and the question?

In both cases there is a central stronghold that needs to be destroyed. The cancer tissue is like the king's fort. The general's army is like the ray that has the capacity to destroy the stronghold but cannot be employed in its full intensity. When mapping the clues from the two stories, one of the characteristics from the first story can be adapted as the solution.

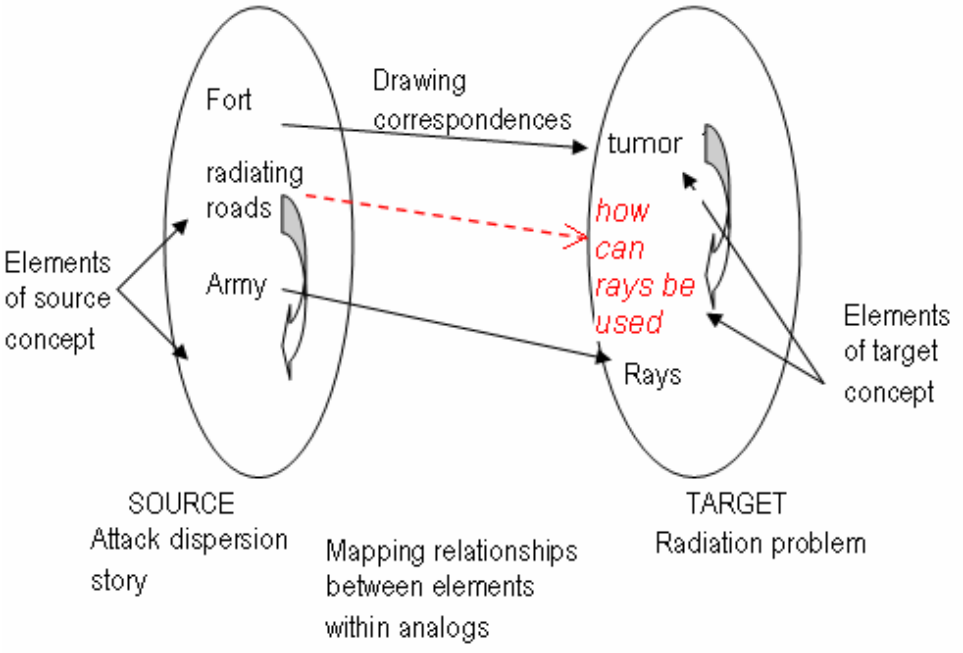


Figure 3. Mapping clues between stories

The above figure represents the cognitive process of creating and understanding analogies. Considering the solution you came up with in the last activity, you drew parallels or correspondences between the source analog, the attack dispersion story and the target analog, the problem. You compared the elements in the two analogs: the central focus is the fort which is like the tumor, the central focus in both the analogs must be destroyed using the army which is like the rays in the problem. Once you are able to make these matches you identify the areas of mismatch which is the relationship between the fort and army, and the tumor and the rays. Since you know the relationship between the fort and army, you map this relationship between the elements of the source analog onto the relationship of the elements of the target analog to determine a solution that the rays can be divided to attack the tumor like the army attacked the fort.

Hence, generalizing this process of analogical mapping is the figure below.

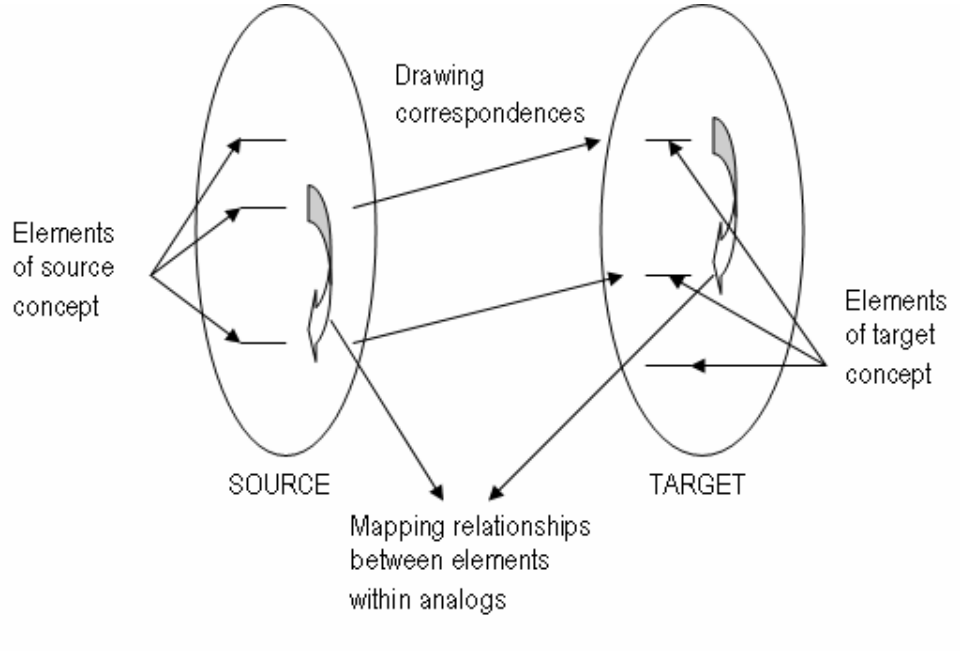


Figure 4. Cognitive process of analogical mapping

When communicating with people from different disciplines you may want to use source analogs that are common. These source analogs may be routine activities, prior shared experiences within the group, or any knowledge with which your audience is familiar. Common knowledge is a common ground beyond which extensions can be made. Additionally, prior knowledge facilitates understanding and learning so your audience would be able to relate to the new concepts you talk or write about.

**What are the characteristics of effective analogies in cross disciplinary and cross functional communication?**

Effective analogies correspond to substantial knowledge transfer and accurate understanding. The following are the characteristics of effective analogies:

1. Simple source analogs
2. Structural source analogs
3. Central analogy

4. Visual analogy
5. Extended analogy

Simple source analog – Selecting a source analog that is well known to your audience will help them relate to the new concept. A simple source analog is prior knowledge of which only element corresponds to an element in the target analog. This makes the mapping between the two analogs clear. A possible solution to using complex source analogs is by making a visual analogy to elucidate the correspondences between the analogs.

Structural source analog – Structural analogies have similar underlying structures but different superficial features. Structural analogies are generally from different domains of knowledge. Using analogies with similar superficial structures can interrupt knowledge transfer.

Central analogy – When explaining a disciplinary concept, determine the principle or main point of the concept and use a source analog to highlight only that concept. Provide a brief idea about the concept before and after the analogy. Using an analogy to talk about the peripheral aspects of a concept can highlight these peripheral aspects. This may lead to inaccurate knowledge transfer.

Visual analogy – Draw a visual analogy to show the correspondences between the source and target analog.

Extended analogy – Extending an analogy means drawing correspondences between the source and target analog beyond a simple mention of their similarity.

The following is an example of an effective analogy which was created by a senior undergraduate management student.

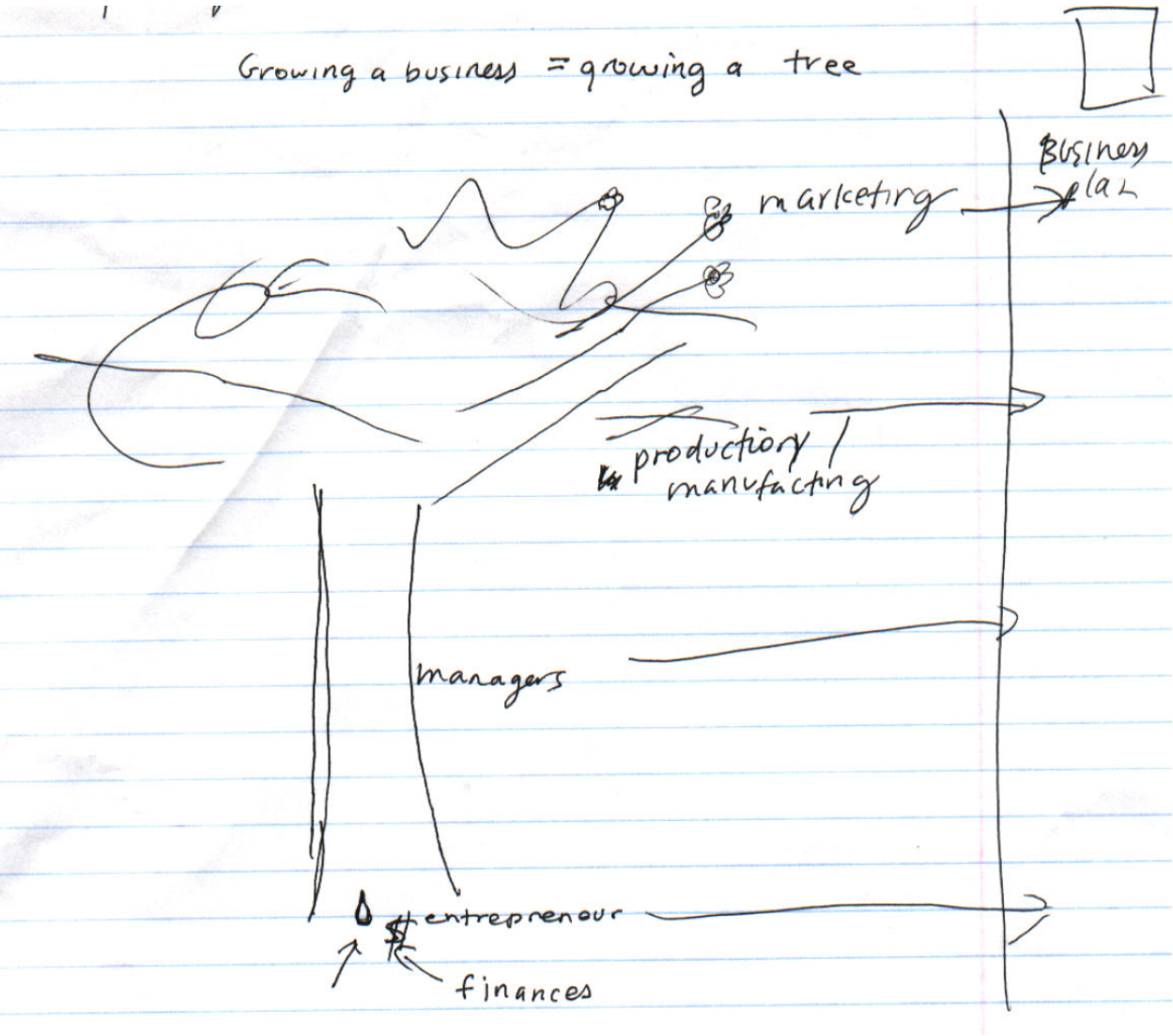


Figure 5. Visual analogy for business plan made by student

Simple analog – growing a tree is a concept familiar to all

Disciplinary concept – Business plan

Structural analog – Growing a business is like growing a tree and a business plan has all the ingredients for growing a business.

Extending analogy – A seed is like the entrepreneur who has the product or service idea to start the business just like the seed has the potential tree. The seed needs water and nutrients to grow which are like finances, legal and political support for the business. Once the plant starts to grow

it develops branches, these branches are like the small functional departments that conduct the specialized activities in a growing business. Later the tree has a structure like the organizational structure, and develops a trunk that supports the branches and the whole tree. The trunk of the tree is the management in the organization that holds the organization and controls its functioning. The tree has flowers that are very pretty and attract onlookers, birds and bees. These flowers are the marketing department of the organization that makes attractive advertisements and sales programs to attract customers. So all this that makes up the business has to be written down in the business plan.

The contents of a business plan are explained around the analogy of growing a tree in this example, so it is a central analogy using a simple source analog of growing a tree.

**What are metaphors?**

The essence of a metaphor is, understanding the aspects of one thing in terms of another. It involves blending and/or mapping of aspects from different domains. Metaphors have been considered to be poetic by many people, but previous research argues that most of our conceptual thinking is metaphorical (Lakoff & Johnson, 1980). This means that our conceptual system in terms of which we think, act, what we experience and what we do every day is metaphorical in nature. And since language use reflects the way we think or our conceptual system, language use is important evidence that much of our thought is structured by commonly used metaphors. For example, in the United States when we say “you are wasting my time”, “I’ve invested a lot of time in this course”, “Thank you for your time”, we are unconsciously using the metaphor ‘time is money’. The prevalent use of this metaphor indicates that in our conceptual system time is a valuable resource. This reflects a value system and a way of understanding an abstract concept that is culturally bound and structured largely by language use.

Metaphors can also be used consciously. For example, the phrase "these are the foundations of my theory", is often an unconscious use of the conceptual metaphor 'theories are buildings'. However, the phrase "these facts are the bricks and mortar of my theory", is an extension of the metaphor that is often used consciously.

Cornelissen, in 2005 demonstrated that metaphors can help communication across domains/disciplines. When we say that "don't *waste* your time" or "I have *invested* a lot of time in this course", by using the words waste and invest, you are imposing the knowledge of the domain of resource management when talking of time.

So when you are in cross-functional or interdisciplinary teams, learning how to consciously and effectively use metaphors can help you explain certain domain-specific concepts using language that is common to both domains.

**Difference between analogies and metaphors**

The difference between analogies and metaphor lies in the way they work. Analogies *map* the relationships between the elements of the source analog onto a target analog, while metaphors work by *blending* and/or mapping the two domains in order to explain certain aspects of a domain through another domain. For example, in the statement "these facts are the bricks and mortar of my theory", I blend the two domains in one sentence to explain that these facts are the building blocks of my theory. Whereas if the idea was to be conveyed as an analogy it would be building: bricks and mortar:: theory: facts. In spoken language this can be phrased as "these facts to my theory are like bricks and mortar to a building".

**Steps to create effective analogies and metaphors**

1. Know the concept you need to explain

2. Know the necessary aspects of the concept you need to explain – determine the principle or main points of the concept that you would like to create an analogy for. If possible this principle or central point of the concept should be explained by the source analog and the peripheral points of the concept by extending the analogy.
3. Know the background of your audience – If you are addressing audience of a particular discipline or function you may want to use a concept from their discipline which is similar to the concept you want to talk about. If you are addressing audience from a variety of disciplines and functions then you may want to pick source analog from routine activities, current affairs or other common knowledge bases.
4. Draw similarities between the concept and the topics familiar to your audience – To select the source analog, first draw similarities between two concepts to see if they map
5. Shape them into analogies and/or metaphors

**Group activity 2**

In a group, go through the steps of creating analogies and metaphors to complete the following table:

| **Topic** | **Discipline the audience is familiar with** | **Similarities between product design and topics from finance** | **Analogy and metaphor usage** |
|---|---|---|---|
| Process of product design | Finance | | |

Solution

| **Topic** | **Discipline the audience is familiar with** | **Similarities between product design process and topics from finance** | **Analogy and metaphor usage** |
|---|---|---|---|
| Process of product design | Finance | **Finance terminology:** Budgets | Analogy - Investing is like design constraints as you know how much you want to invest for |

| Topic | Discipline the audience is familiar with | Similarities between product design process and topics from finance | Analogy and metaphor usage |
|---|---|---|---|
| | | Profits<br>investing<br>Money/cash flow<br><br>**Product design concepts:**<br>Design constraints<br>Resources and capacity optimization | but what can invest is limited.<br>Extending analogy - Also investing is necessary to achieve goals just like investing in resources in necessary to design a product.<br><br>Analogy - Using resources optimally is like defining budgets to maintain a steady yet restricted cash flow. |

**Group activity 3**

In your interdisciplinary groups, each of you may select a concept from your discipline and explain it. To explain the topic, introduce the concept, then use a simple, structural, central and visual analogy, and provide one extension of the analogy (comparison between the source and target analog). Your group members should try and add an extension to the analogy (comparison between the source and target analog) one at a time. This game is like Chinese whispers only here your group members will mention the extensions (comparisons between the two analogs) out loud.

# Appendix B

**Pre-test**

*Pretest instructions*

1. Group formation: Please form groups of three such that no two members are from the same discipline or function.
2. Topic selection: Each of you needs to select three technical topics that are specific to your field of study or function. You must know these topics or concepts well, and be able to explain them with confidence. These topics may be concepts or methods. For example, since my major is Industrial and Systems Engineering, I would select Kanban system.
3. Try to select topics that most of your team members are unfamiliar with, in case some of them are familiar with any of your topics, select those topics that your group members cannot confidently explain.
4. You may take the next 5 minutes to select and confirm these topics after forming your groups.
5. Over the next week, until till the next class, think of ways in which you would explain any one of these topics to all your group members.
6. You must remember that your explanation should provide a general sense of the topic to your colleagues. In addition to explaining verbally, you may use diagrams or drawings if useful.
7. You may make notes before giving the explanation on the sheet of paper provided.
8. (Next class) Now each of you must explain your concept to the other group members. Immediately after everyone's explanation, the other two will complete questionnaires 1 and 2 provided. Please write down your names on each of the questionnaires.

9. (After all explanations are given and questionnaires complete) Now evaluate questionnaire 2 your group members completed for the topic you explained. Rubric 1 will be provided to you to help you make the evaluations.

**Questionnaire 1**

Your name:

| | | | | | |
|---|---|---|---|---|---|
| 1 | Name of the topic explained to you | | | | |
| 2 | I could describe the concept confidently before it was explained to me | [ ] Strongly Agree | [ ] Agree | [ ] Disagree | [ ]Strongly Disagree |
| 3 | He/she explained the concept well | [ ] Strongly Agree | [ ] Agree | [ ] Disagree | [ ]Strongly Disagree |
| 4 | I can now describe the topic/concept correctly with confidence | [ ] Strongly Agree | [ ] Agree | [ ] Disagree | [ ]Strongly Disagree |

**Questionnaire 2**

Your name:

Name of the topic explained to you:

Restate the main points of the topic in you own words. For example, green engineering design stresses on the reduction of usage of perishable resources, pollution and waste in the input, manufacturing, usage and disposal stages of a product.

Provide an application of this concept/ topic.

For example, for the concept Green engineering, an application would be the design of cars that use alternate sources of fuel, and produce lower or no carbon dioxide and can be made with recyclable metal.

Justify the application you suggested, by creating connections between the concept and your application.
For example, using alternate sources of fuel – reduces usage of gasoline (perishable source of energy); producing lower or no carbondioxide – ensures lesser pollution in the usage stage; and using recyclable metal to manufacture the car body – ensures lesser waste, recycled use of perishable resource (metals) during manufacturing

Instructions to evaluate answers from questionnaire 2

You must evaluate the answers from questionnaire 2 given the guidelines in rubric 1. Complete the table given below the rubric with the scores.

**Rubric 1**

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Vocabulary | Summary does not use any words similar to the ones you used to explain | Summary uses few similar words but no same words as you used | Summary uses some similar words and a few same words used by you | Summary mostly uses same and similar words used by you |
| Knowledge transfer | Not all main points were stated | All main points were stated | All main points and application stated | All main points, application and justification of application stated |
| Accuracy in interpretation | There are deep inaccuracies in the main points | The main points are accurate/ correct, but the application(s) is not | The main points and application(s) are accurate/ correct but the | The main point(s), application(s) and the justification are |

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| | | | justification is not accurate | accurate |

| | |
|---|---|
| Your name: | |
| Topic you explained: | |
| Group member's name – | Vocabulary – |
| | Knowledge transfer- |
| | Accuracy in interpretation – |
| Group member's name – | Vocabulary – |
| | Knowledge transfer– |
| | Accuracy in interpretation – |

(Questionnaires 1, 2 and the evaluation tables will be on three separate pages which would be given to participants when instructed. Also, blank sheets will be provided to participants to make notes. All these sheets will be collected from participants after the test.)

**Instruction 1**

*Analogies*

*What are analogies?*

Analogies allow mapping the features of a familiar concept onto a more unfamiliar concept to learn more about it. The more familiar and better understood concept is called the source analog and the unfamiliar one for which we seek information is the target analog. The source and target may be concepts, methods, ideas or objects from different domains.

Analogies have been shown to be useful in reasoning and may encourage creativity. In fact, some of the major scientific theories are founded on analogies. For example, the planetary

model of the atomic structure, “billiard ball” model of gases, and hydraulic model of the blood circulation system. These analogies may have been used in high school to teach you basic concepts. For example, most explanations of the structure of an atom involve a visual analogy to the structure of our solar system. In these analogies, the nucleus is at the center like the sun and the electrons revolve around it like the planets (Gick, 1980).

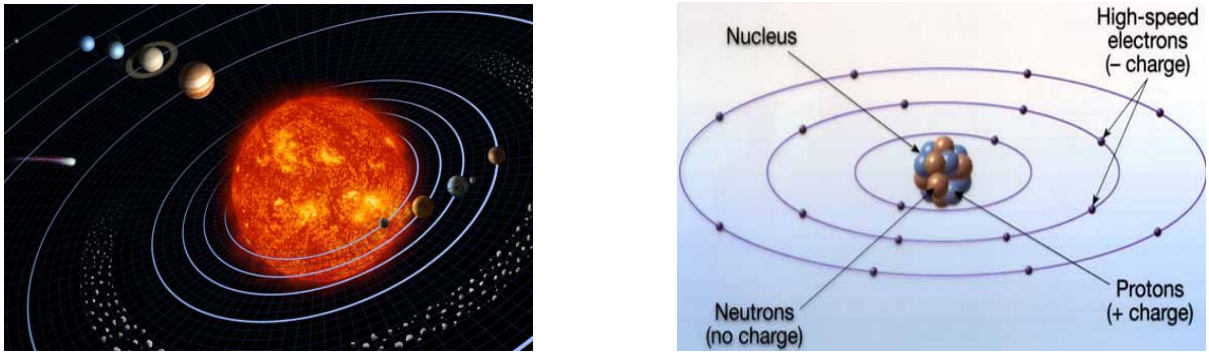


Figure 1. The planetary model of atomic structure

In this example the domain knowledge of astronomy is mapped to understand the structure of the atom. Even in graduate school, analogies both verbal and visual are employed as tools to explain unfamiliar concepts.

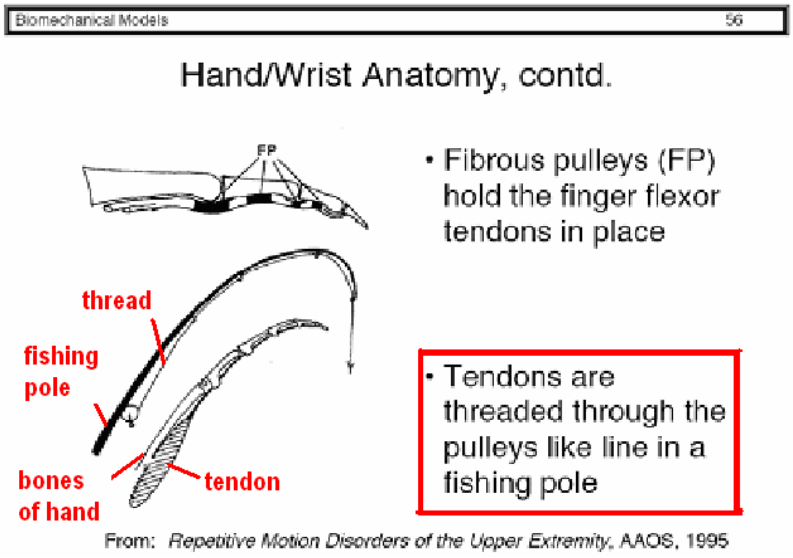


Figure 12. Fishing pole analogy for tendons in fingers (Gordon, 1995)

This is a slide for a chapter 'Biomechanical models' of a graduate level course, 'ISE - 5614, Human Physical capabilities'. The objective of the lower diagram is to explain the function of tendons in our hand/wrist. To explain this, our hand is compared to a fishing pole and the tendon to the fishing thread that pulls the bait up or down. So, when we have to bend the tips of our fingers, the tendons pull the bones at the tips of our fingers to cause that action like the thread pulls the bait from the rod end. Also, the tendon is attached to the bones like the thread is put through holes in the fishing rod. Notice how the hand anatomy is explained using an analogy from an area that is known or common to all.

Another analogy that was used to explain an aspect in submarine design is given in Figure 3.

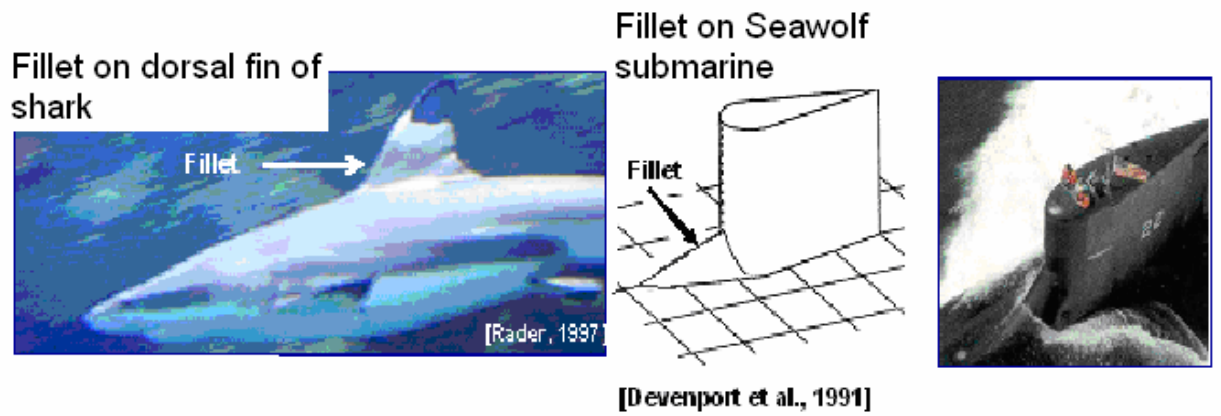


Figure 3. Design concept borrowed from sharks – fillet on the dorsal fin (Alley, 2007)

In this example, the function of a particular component is mapped onto another domain or discipline. This is also an example of how analogies can help solve design problems. Such analogies also help in knowledge transfer across disciplines.

*How do analogies work?*

Generally these two analogs have some common patterns of relationships among their constituent elements. Once source and target concepts are known, key features and hence

similarities between the two are identified. Analogies work by drawing correspondences between the elements of the source and the target as shown in Figure 4. This way, characteristics of the target analog and the relationships between its elements are inferred by mapping this information from the source analog to the target analog.

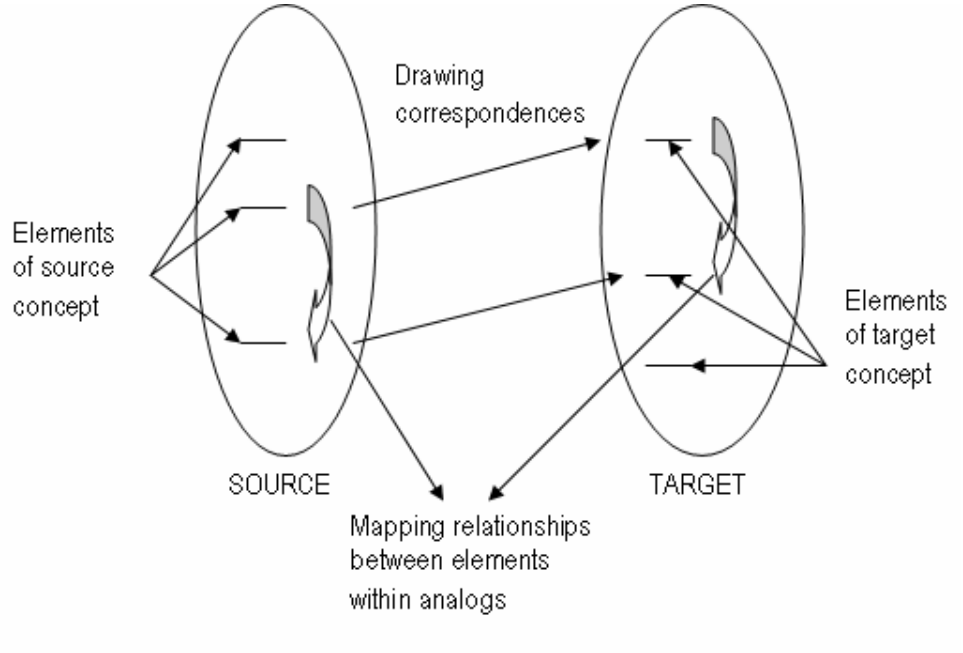


Figure 4. Process of interpreting through analogical mapping

The analogies seen in aptitude tests and other exams are of the form: a:b :: c:?

Let's say *Hand: Finger :: Foot: ?*

Answer: Toe

Let's analyze how our minds must have come to answer 'toe'. In this case the source analog is hand: finger. And since we need to find out foot: ? that becomes the target analog. We draw correspondences between hand and foot and finger and ?. This way we understand that there is an asymmetry. We then look at the relationship between hand and finger, and map that relationship onto foot and the missing information.

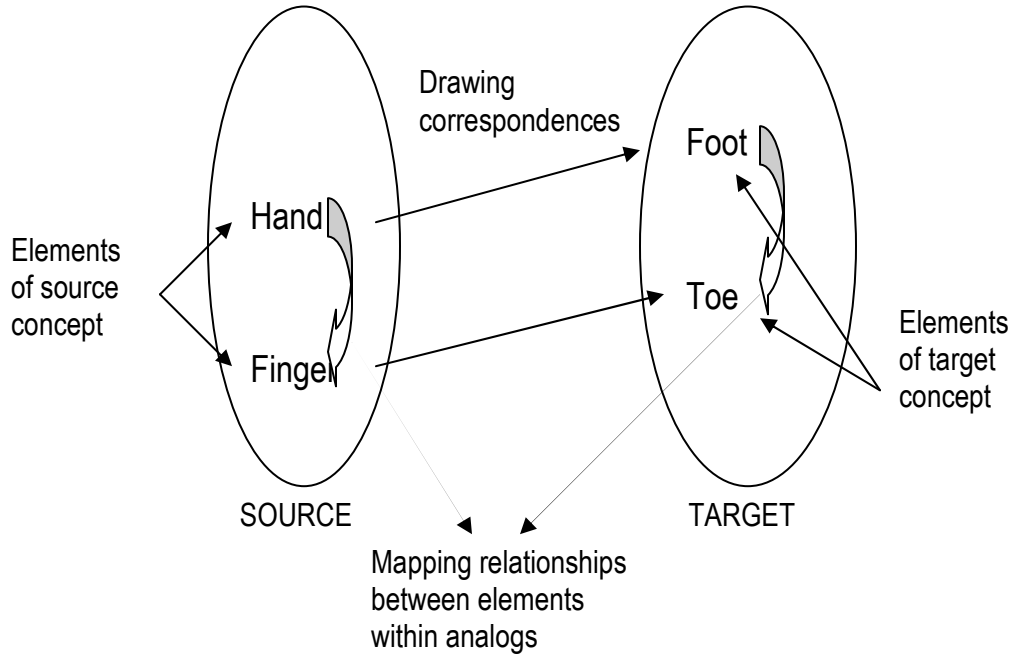


Figure 5. Analogical mapping for example

By now you can *define* and *identify* analogies, compare analogs and *interpret* information about the unfamiliar. The next activity will teach you to *identify* and *select* relevant source analog(s) and *apply* them to *derive* solutions to a given problem.

*Activity 1 - Activity to practice relevant source analog identification, retrieval and selection*

(Participants must form into groups of at least three. Each member would be given three stories and then one problem. They have to solve the problem as a group).

You have been each given three stories. After reading three by yourself, you must work in your group to solve the problem provided to you after this.

The three stories from Gick and Holyoak (1980), pg 353-354:

*The Attack-Dispersion story*

A small country was ruled (from a strong fortress) by a king. The fortress was situated in the middle of the country surrounded by farms and villages. Many roads radiated outward from

the fortress like spokes of a wheel. 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. However, the general learned that the king 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 king 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 and render it impassable, but it would also destroy many neighboring villages. It therefore seemed impossible to mount a full-scale direct attack on the fortress. 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. Each group continued down its road to the fortress so that the entire army finally arrived together at the fortress at the same time. The fortress fell and the king was forced to flee into exile.

*The wine merchants*

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 sent out for the duke's palace at once. An hour before sundown they came to a place where the bridge had been washed down 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. Te cart overturned, and the horses, the wine, and the driver were washed away.

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 identical twins*

Once there were identical twins that 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 where 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.

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 broadjumping event. The race began and the students rushed into the woods. The twin rushed into the woods and waited until the others had 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 the event.

Each of you is now given a 'radiation problem'. You must read the problem individually and then come together as a team to solve it. This activity is to teach you to identify the

similarities between the stories and select the relevant source analog. In this case, either of these three stories has a solution or a situation that could be mapped onto the radiation problem.

For example, Naval mines have been used since 1776. Throughout the World war II, submarines had planted 576 mines, resulting in 27 ships sunk and 27 damaged, or one ship per 10 planted mines (source: http://www.fas.org/man/dod-101/sys/ship/weaps/mines.htm). In Dec 2002, the National Geographic news reported that a Program Manager at the Office of Naval Research was looking for a "quick and accurate method for detection of naval mines". He and his colleagues then sought to understand how bats and dolphins make sounds and process the sounds' echoes to create three-dimensional reconstructions of objects in their environment ("Sonar " 2007). In this way, the Naval researchers arrived at a solution by mapping a method from another domain.

You have to map the idea(s) from any of the stories to find a solution to solving the problem.

*The radiation problem (adapted from Gick and Holyoak (1980), pg 307-308):*

Read the problem individually before you come together to discuss the solution. Please write the solution in about 100 words as a group.

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 a 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. 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? What are some answers?

While solving the problem did you think that any of the three stories given above had similarities to this problem? Which one? The Attack-Dispersion problem. What are the similarities? In both cases there is a central stronghold that needs to be destroyed. The cancer tissue is like the king's fort. The general's army is like the ray that has the capacity to destroy the stronghold but cannot be employed in its full intensity.

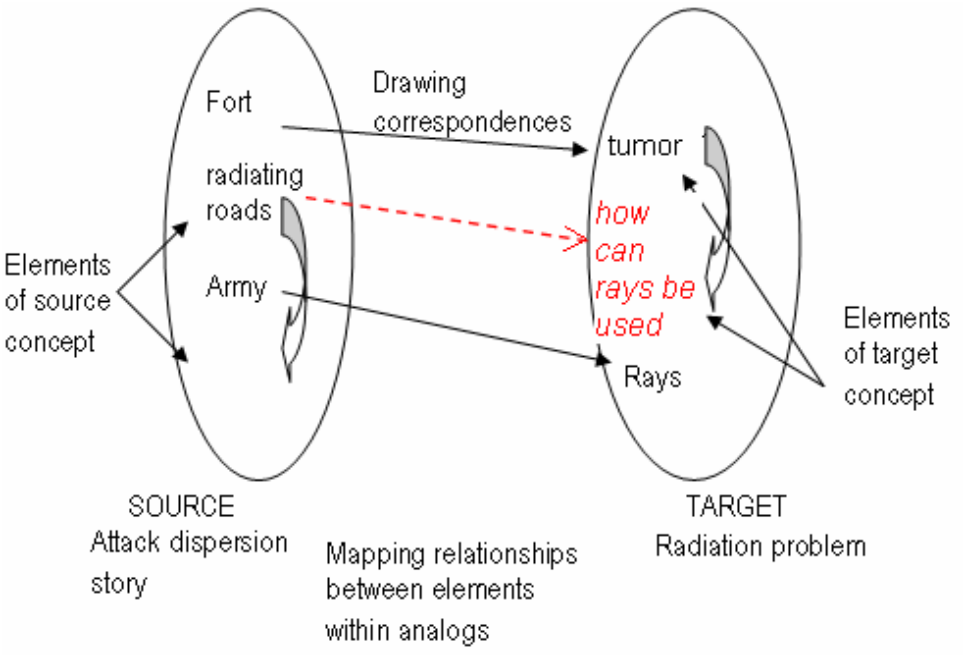


Figure 6. Mapping clues between stories

When mapping the clues from the two stories, one of the characteristics from the first story can be adapted as the solution. The ray may be broken into rays of smaller intensity approaching from different directions simultaneously at the center to create a higher intensity ray. This would destroy the tumor.

*How are analogies different from examples?*

Previous research explains a method called analogical encoding in which learners compare two examples to understand an unfamiliar concept. Providing two examples helps

learning more than just stating one. This way, the learners compare the two examples and draw out the common underlying principles from the two examples. These common underlying principles help explain the unknown concept (Gentner, 2003; Loewenstein, 1999).

*Activity 2: Analogical encoding*

You would be given one case/ example, after reading the example you must answer the following question. Then you would be given the second case/ example. You must answer the same question again.

Please be very brief in answering the question. The cases have been taken from Appendix B of Loewenstein, 1999.

Case 1: Syd, a recently-promoted head buyer of a major retail store, has bought some wholesale goods from an Asian Merchant. All aspects of the deal have been successfully negotiated except the transfer of the goods. The merchant tells Syd that he will pay to ship the goods by boat. Syd is concerned because the US has announced that a trade embargo is likely to be placed on all goods from that country in the near future. The Asian merchant tells Syd not to worry because the boat will arrive at the US dock before the embargo occurs. Syd, however, thinks the boat will be late. Syd wants the merchant to pay to ship the goods by freight (which is substantially more expensive). The merchant refuses because of the higher cost. They argue about when the boat will arrive.

The Asian merchant suggests that they "make a bet". The Asian merchant will ship the goods air freight but they will both watch when the boat actually docks in the US. If the boat arrives on time (as the Asian merchant believes it will), Syd will pay for all the air freight. However, if the boat arrives late (as Syd believes it will), the Asian merchant will pay the entire air freight bill.

Question: What is a contingency contract?

Case 2: Two fairly poor brothers, Ben and Jerry, have just inherited a working farm whose main crop has a volatile price. Ben wants to sell rights to the farm's output under a long-term contract for a fixed amount rather than depend upon shares of an uncertain revenue stream. In short, Ben is risk-averse. Jerry, on the other hand is confident that the next season will be spectacular and the revenues will be high. In short, Jerry is risk seeking. The two argue for days and nights about the price of the crop for next season. Ben wants to sell now because he believes the price of the crop will fall; Jerry wants to hang onto the farm because he believes that the price of the crop will increase. Jerry cannot to buy Ben out at this time.

Then, Jerry proposes to bet to his brother: They keep the farm for another season. If the price of the crop falls below a certain price (as Ben thinks it will), they will sell the farm and Ben will get 50% of today's value of its worth, adjusted for inflation; Jerry will get the rest. However, if the price of the crop rises (as Jerry thinks it will), Jerry will buy Ben out for 50% of today's value of the farm, adjusted for inflation, and keep all of the additional profits with himself.

*Solution adapted from Loewenstein, 1999; pg 588:*

Contingency contracts capitalize on parties' differing expectations regarding the outcome of a future event. Each party is willing to proceed with an agreement by stating terms for the outcome each thinks will occur, thereby minimizing risk and maximizing expected outcomes. For instance, a producer and a theater owner are at an impasse over negotiating costs associated with mounting a new production: The producer predicts sold-out shows and demands a correspondingly high price, whereas the theater owner has more modest expectations and, thereby, wishes to minimize costs. Rather than compromising on a midpoint between their initial

proposals, they can agree that the producer will get 60% of the revenues if more than 90,000 seats are sold, but only 40% of the revenues if fewer seats are sold.

*Activity 3: Generating analogies*

The next activity will teach you to *generate* analogs:

For example:

Sun : Solar system

Heart : _____

_____ : _____

In the above example, the relationship between the sun and the solar system must be mapped onto the target analogies to determine the unknown element in the target analogy (Heart: _____ ). Here the 'sun' is central to the solar system both in existence and physical layout. Without the sun's light and gravitational forces the planets of the solar system may not revolve around their orbits and remain a coherent solar system.

Similarly, the heart is central to 'living' or 'circulatory system'. Now generate an analogy on the same lines as the previous analogies. Something like driver: car, assuming there are no automatic vehicles!

Now fill in the blanks by generating elements of the target analogy and hence generating analogies on the same lines:

1. Gear train: cogs (gear teeth)

   Team : _____

   _____: Ingredients

   _____ : _____

2. Marketing: customer

   Cooking : _____

   _____ : _____

*Possible solutions to Activity 3:*

1. Gear train : cogs (gear teeth)

   Team : *members*

   *tasty dish/ recipe* : Ingredients

   *Word : Letters*

   *Painting : colors*

2. Marketing : customer

   Cooking : *diner*

   *Artist : museum patron*

*Metaphors*

*What are metaphors?*

The essence of a metaphor is, understanding the aspects of one thing in terms of another. It involves blending and/or mapping of aspects from different domains. Metaphors have been considered to be poetic by many people, but previous research argues that most of our conceptual thinking is metaphorical (Lakoff & Johnson, 1980). This means that our conceptual system in terms of which we think, act, what we experience and what we do every day is metaphorical in nature. And since language use reflects the way we think or our conceptual system, language use is important evidence that much of our thought is structured by commonly used metaphors. For example, in the United States when we say "you are wasting my time", "I've invested a lot of time in this course", "Thank you for your time", we are unconsciously using the metaphor 'time

is money'. The prevalent use of this metaphor indicates that in our conceptual system time is a valuable resource. This reflects a value system and a way of understanding an abstract concept that is culturally bound and structured largely by language use.

Metaphors can also be used consciously. For example, the phrase "these are the foundations of my theory", is often an unconscious use of the conceptual metaphor 'theories are buildings'. However, the phrase "these facts are the bricks and mortar of my theory", is an extension of the metaphor that is often used consciously.

Cornelissen, in 2005 demonstrated that metaphors can help communication across domains/disciplines. When we say that "don't *waste* your time" or "I have *invested* a lot of time in this course", by using the words waste and invest, you are imposing the knowledge of the domain of resource management when talking of time.

So when you are in cross-functional or interdisciplinary teams, learning how to consciously and effectively use metaphors can help you explain certain domain-specific concepts using language that is common to both domains.

*Difference between analogies and metaphors*

The difference between analogies and metaphor lies in the way they work. Analogies map the *relationships* between the elements of the source analog onto a target analog, while metaphors work by blending and/or mapping the two domains in order to explain certain aspects of a domain through another domain. For example, in the statement "these facts are the bricks and mortar of my theory", I blend the two domains in one sentence to explain that these facts are the building blocks of my theory. Whereas if the idea was to be conveyed as an analogy it would be building: bricks and mortar:: theory: facts. In spoken language this can be phrased as "these facts to my theory are like bricks and mortar to a building".

Now that you can define and identify metaphors, the next activity will help you *identify* and *infer* metaphors.

For example, "he attacked every weak point in my argument". The phrase 'attacked every weak point' likens argument to war. Argument has many aspects. It involves listening to the other person's views and giving your own and then contradicting the other person. By using this metaphor of war, we are highlighting the aspect that in an argument people contradict the other.

*Activity 4: Generate and apply metaphors:*

For example, concept: integration of ideas

Metaphor: mesh of ideas. The metaphor 'mesh' refers to:

1. A connection of things (thread) or woven pieces (web)
2. To the gear teeth fitting in correctly

Considering these meanings, 'mesh' essentially connects or fits things/ideas/functions together.

Used in a sentence: The design of the new product was a mesh of ideas of the team members.

Think of and write down metaphors for 'opportunity', and make a sentence using any one of the metaphors to complete the table in not more than 5 minutes. Please work with your group.

| Concept | Metaphor | Usage in sentence |
|---|---|---|
| Integration | Mesh, Bind, Tie, Build | The design of the new product was a mesh of ideas of the team members |
| Opportunity | | |

Possible solutions to activity 5:

| Concept | Metaphor | Usage in sentence |
|---|---|---|
| Integration | Mesh, Bind, Tie, Build | The design of the new product was a mesh of ideas of the team members |
| Opportunity | *Window, light, room,* | *With such a packed plan I think we have closed all* |

| Concept | Metaphor | Usage in sentence |
|---|---|---|
| | *door* | *windows for surprise.* |

You are now able to describe, create and infer analogies and metaphors. You are also aware that analogies and metaphors may have the potential to support explaining unfamiliar concepts to people from different disciplines/functions. This may be in the verbal (spoken or written) or visual form.

Let's apply these tools to explain our technical concepts to other members like we did earlier.

**Posttest 1**

*Posttest 1 instructions*

1. Pick one of the two topics you haven't already used from the activity earlier.
2. Think of ways to explain the topic in 2 minutes or less over the week. Remember that your explanation should provide a general sense of the topic to your colleagues. In addition to a verbal explanation, you may use drawings or diagrams if useful. Remember to use analogies and metaphors in your explanations.
3. You may make notes on the sheet given.
4. (After one week) Now each of you must explain your concept to the other two. Immediately after everyone's explanation, the other two will complete questionnaires 3 and 2 provided. Please write down your names on each of the questionnaires.
5. (After all explanations are given and questionnaires complete) Now evaluate questionnaire 2 your group members wrote for the topic you explained. A rubric 2 will be provided to help guide your evaluations.

**Questionnaire 3**

Your name:

| | | |
|---|---|---|
| 1 | Name of the topic explained to you | |
| 2 | I could describe the concept confidently before it was explained | [ ] Strongly Agree [ ] Agree [ ] Disagree [ ]Strongly Disagree |
| 3 | He/she explained the concept well | [ ] Strongly Agree [ ] Agree [ ] Disagree [ ]Strongly Disagree |
| 4 | I can now describe the topic/concept correctly with confidence | [ ] Strongly Agree [ ] Agree [ ] Disagree [ ]Strongly Disagree |
| 5 | He/she used analogies and metaphors in the explanation | [ ] Yes [ ] No |
| 6 | He/she explained the concept better this time than last time | [ ] Strongly Agree [ ] Agree [ ] Disagree [ ]Strongly Disagree |
| 7 | When you think about the topic now, do you think of any of the analogies and metaphors used to explain it | [ ] Yes [ ] No |
| 8 | The analogies and/or metaphors used in the explanation helped me understand the topic better | [ ] Strongly Agree [ ] Agree [ ] Disagree [ ]Strongly Disagree |
| 9 | It would be easier to understand the topic without analogies or metaphors | [ ] Strongly Agree [ ] Agree [ ] Disagree [ ]Strongly Disagree |

**Questionnaire 2**

Your name:

Name of the topic explained to you:

Restate the main points of the topic in you own words. For example, green engineering design stresses on the reduction of usage of perishable resources, pollution and waste in the input, manufacturing, usage and disposal stages of a product.

Provide an application of this concept/ topic.
For example, for the concept Green engineering, an application would be the design of cars that use alternate sources of fuel, and produce lower or no carbon dioxide and can be made with recyclable metal.

Justify the application you suggested, by creating connections between the concept and your application.
For example, using alternate sources of fuel – reduces usage of gasoline (perishable source of energy); producing lower or no carbon dioxide – ensures lesser pollution in the usage stage; and using recyclable metal to manufacture the car body – ensures lesser waste, recycled use of perishable resource (metals) during manufacturing

*Instructions to evaluate answers of questionnaire 2*

You must evaluate answers from questionnaire 2, using rubric 2 as a guide. Complete the table given below the rubric with the scores.

**Rubric 2**

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Vocabulary | Summary does not use any words similar to the ones you used to explain | Summary uses few similar words but no same words as you used | Summary uses some similar words and a few same words used by you | Summary mostly uses same and similar words used by you |
| Knowledge transfer | Not all main points were stated | All main points were stated | All main points and application stated | All main points, application and justification of application stated |
| Accuracy in interpretation | There are deep inaccuracies in the main points | The main points are accurate/ correct, but the application(s) is not | The main points and application(s) are accurate/ correct but the justification is not accurate | The main point(s), application(s) and the justification are accurate |
| Use of analogy and/or metaphor | Summary did not mention any analogy or metaphor | Summary mentions analogy and/or metaphor(s) that was not used in my explanation AND does not/incorrectly explains the concept<br>Or<br>Summary mentions analogy and/or metaphor that was used in my explanation BUT does not explain concept correctly | Summary mentions analogy and/or metaphor(s) used in the explanation AND correctly explains concept | Summary mentions analogy and/or metaphor(s) that was not used in my explanation AND correctly explains concept |

| | |
|---|---|
| Your name: | |
| Name of topic you explained: | |
| Group member's name – | Vocabulary – |
| | Knowledge transfer - |
| | Accuracy in interpretation – |
| | Use of analogy and/or metaphor – |

| | |
|---|---|
| Group member's name – | Vocabulary – |
| | Knowledge transfer– |
| | Accuracy in interpretation – |
| | Use of analogy and/or metaphor – |

(Questionnaires 3, 2 and the evaluation tables will be on three separate pages which would be given to participants when instructed. Also, blank sheets will be provided for participants to make notes. All these sheets will be collected from participants after the test).

**Instruction 2**

In the last activity you used analogies and/ or metaphors to explain your topics to your colleagues. You used analogies or metaphors, but how would you ensure that your audience understands those analogies or metaphors? Did you think about how your audience would interpret or understand the analogies and metaphors?

Analogies and metaphors must be chosen depending on:

1. <u>The background of the audience you are addressing</u> – Select source analogs and source domains for analogies and metaphors with which the audience is familiar.
    - You may use an analogy or metaphor from the discipline/ function to which your colleague(s) belong
    - If your audience is composed of people from different backgrounds select analogies from domains of knowledge that are common to all of them. For example, if I want to explain the concept of Kanban to an audience comprising of people from Sciences, Arts, Management and Engineering, I would say that Kanban is a pulling system used in manufacturing. Like in a grocery store there are racks for each commodity, and when the commodity gets finished on these

racks due to sales, the store keepers refill the racks for more of the commodity, the Kanban system works in a similar manner. There are bins to keep the components for product. When manufacturing the final product these components are used up. Once the bins are empty for the components, they are refilled from the inventory and in turn more components are ordered for the inventory. In this way it is a pull system to manage inventory in manufacturing. Here I used the analogy of a grocery store with which all of us are familiar and hence have knowledge of this domain. This analogy also highlighted the process of inventory replenishment, which here is the main concept. You must think of relevant analogies and metaphors in this manner to explain your technical concepts.

2. <u>The aspect or property of the unknown concept you need to emphasize</u> – You must select a source concept that highlights the aspect of the unknown concept you want to emphasize. For the Kanban example, I am emphasizing on the process of 'pulling' to replenish inventory. There is a lot of other information available on Kanban system, but this analogy emphasizes the 'pulling system'.

*Activity 5: Retrieve, identify, select and generate effective analogies and metaphors:*

The objective of this activity is to help you generate analogies and/or metaphors that can be easily understood by your audience. The table given to you specifies the discipline/function to which your audience belongs. You must work on this activity individually to *identify* similarities between the product design and any topic(s) from finance/ accounting and *create* analogies and/or metaphors from them. Please take 2 minutes or less to complete the table.

| Topic | Discipline/functions audience is familiar with | Similarities between product design and any topic(s) from finance/accounting | Analogy and metaphor usage |
|---|---|---|---|
| Product Design | Finance/ accounting | | |

Possible solutions to activity:

| Topic | Discipline/functions audience is familiar with | Similarities between product design and any topic(s) from finance/accounting | Analogy and metaphor usage |
|---|---|---|---|
| Product Design | Finance/ accounting | *Design constraints are like the budget*<br>*The criteria to optimize costs are like trying to make the most innovative product but without going beyond the constraints of time, etc.* | *Analogy: Design constraints are like the budget which should not be exceeded.*<br>*Metaphor: Product design budgets the resources available.* |

**Posttest 2**

*Posttest 2 instructions*

1. You must explain the last topic from the three that you selected earlier. Please explain this topic to your group members in 2 minutes or less. You must remember that your explanation should provide a general sense of the topic to your colleagues. In addition to a verbal explanation, you may use drawings or diagrams if useful. Remember to use analogies and metaphors in your explanations.
2. You may make notes in the sheet given over the week.

3. (Next class) Now each of you must explain your concept to the other two. Immediately after everyone's explanation, the other two will complete questionnaires 3 and 2 provided. Please write down your names on each of the questionnaires.
4. (After all explanations are given and questionnaires complete) Now evaluate the answers your group members wrote for the topic you explained. Use rubric 2 to guide your evaluations.

**Questionnaire 3**

Your name:

| | | |
|---|---|---|
| 1 | Name of topic explained to you | |
| 2 | I could describe the concept confidently before it was explained to the group | [ ] Strongly Agree [ ] Agree [ ] Disagree [ ]Strongly Disagree |
| 3 | He/she explained the concept well | [ ] Strongly Agree [ ] Agree [ ] Disagree [ ]Strongly Disagree |
| 4 | I can now describe the topic/concept correctly with confidence | [ ] Strongly Agree [ ] Agree [ ] Disagree [ ]Strongly Disagree |
| 5 | He/she used analogies and metaphors in the explanation | [ ] Yes [ ] No |
| 6 | He/she explained the concept better this time than last time | [ ] Strongly Agree [ ] Agree [ ] Disagree [ ]Strongly Disagree |
| 7 | When you think about the topic now, do you think of any of the analogies and metaphors used to explain it | [ ] Yes [ ] No |

| | | | | | |
|---|---|---|---|---|---|
| 8 | The analogies and/or metaphors used in the explanation helped me understand the topic better | [ ] Strongly Agree | [ ] Agree | [ ] Disagree | [ ]Strongly Disagree |
| 9 | It would be easier to understand the topic without analogies or metaphors | [ ] Strongly Agree | [ ] Agree | [ ] Disagree | [ ]Strongly Disagree |

**Questionnaire 2**

Your name:

Name of the topic explained to you:

Restate the main points of the topic in you own words. For example, green engineering design stresses on the reduction of usage of perishable resources, pollution and waste in the input, manufacturing, usage and disposal stages of a product.

Provide an application of this concept/ topic.
For example, for the concept Green engineering, an application would be the design of cars that use alternate sources of fuel, and produce lower or no carbon dioxide and can be made with recyclable metal.

Justify the application you suggested, by creating connections between the concept and your application.
For example, using alternate sources of fuel – reduces usage of gasoline (perishable source of energy); producing lower or no carbondioxide – ensures lesser pollution in the usage stage; and using recyclable metal to manufacture the car body – ensures lesser waste, recycled use of perishable resource (metals) during manufacturing

*Instructions to evaluate answers to questionnaire 2*

You must evaluate the answers from questionnaire 2 as per the guidelines in rubric 2. Complete the table given below the rubric with the scores.

**Rubric 2**

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Vocabulary | Summary does not use any words similar to the ones you used to explain | Summary uses few similar words but no same words as you used | Summary uses some similar words and a few same words used by you | Summary mostly uses same and similar words used by you |
| Knowledge transfer | Not all main points were stated | All main points were stated | All main points and application stated | All main points, application and justification of application stated |
| Accuracy in interpretation | There are deep inaccuracies in the main points | The main points are accurate/ correct, but the application(s) is not | The main points and application(s) are accurate/ correct but the justification is not accurate | The main point(s), application(s) and the justification are accurate |
| Use of analogy and/or metaphor | Summary did not mention any analogy or metaphor | Summary mentions analogy and/or metaphor(s) that was not used in my explanation AND does not/incorrectly explains the concept<br>Or<br>Summary mentions analogy and/or metaphor that was used in my explanation BUT does not explain concept correctly | Summary mentions analogy and/or metaphor(s) used in the explanation AND correctly explains concept | Summary mentions analogy and/or metaphor(s) that was not used in my explanation AND correctly explains concept |

| | |
|---|---|
| Your name: | |
| Name of topic you explained: | |
| Group member's name – | Vocabulary – |
| | Knowledge transfer - |
| | Accuracy in interpretation – |
| | Use of analogy and/or metaphor – |
| Group member's name – | Vocabulary – |
| | Knowledge transfer– |
| | Accuracy in interpretation – |
| | Use of analogy and/or metaphor – |

(Questionnaires 3, 2 and the evaluation tables will be on three separate pages which would be given to participants when instructed. Also, blank sheets will be provided for participants to make notes. All these sheets will be collected from participants after the test).

**Post-study questionnaire**

Your name -

What is your opinion of the instruction on analogies and metaphors that was provided?

Do you think it is helpful to you? How?

What do you think could be done to improve it?

**Follow-up questionnaire**

1. In general when I hear or read, I notice any analogies and/or metaphors, I immediately recognize them/pick them out.

    - o Strongly agree
    - o Agree
    - o Disagree
    - o Strongly disagree

2. Since we worked with analogies and metaphors in class I have used them to explain a topic/make a presentation/write a descriptive paragraph, I tried using an analogy/metaphor to do so (outside of the Green in-class activity)

    - o Strongly agree
    - o Agree
    - o Disagree
    - o Strongly disagree

3. I have NOT attempted to use analogies/metaphors after the instruction and class activities.

    - o Strongly agree
    - o Agree
    - o Disagree
    - o Strongly disagree

4. I consider analogies and metaphors as useful suitable communication tools when *Encircle the one(s) relevant*

    - o A topic must be explained to anyone
    - o A topic needs to be explained to someone from a different background
    - o Convincing someone of something
    - o Thinking outside the box about a topic – to be creative
    - o I don't consider analogies and metaphors to be very useful to me

5. Metaphors and analogies could also be used for the following:

6. In what ways has your knowledge about analogies and metaphors changed due to the activities in class?

## Appendix C

1. Analogies
    a. Speaker initiated
    b. Listener initiated
    c. Speaker and listener use/extend analogy
    d. Listener shows signs of understanding
    e. Type of analogy
        i. Superficial analogy (Analogies with similar superficial features)
        ii. Structural analogy (source and target analog have similar structures and different superficial features – they may be from different domains of knowledge)
        iii. Extension of analogy to further draw correspondences between elements of analogs

2. Metaphors
    a. Speaker initiated
    b. Listener initiated
    c. Speaker and listener use/extend metaphor
    d. Listener shows signs of understanding

3. Visuals
    a. Visual analogy
    b. Not a visual analogy
    c. Speaker initiated
    d. Listener initiated
    e. Speaker and listener use/extend diagram
    f. Listener shows signs of understanding

4. Examples
    a. Speaker initiated
    b. Listener initiated
    c. Speaker and listener use/extend example
    d. Listener shows signs of understanding

5. Feedback
    a. Speaker initiated
    b. Listener initiated
    c. Listener shows signs of understanding

# Appendix D

**Sequence of activities**

1. Pretest
2. Instruction with explanation of analogy (Activity 3)
3. Instruction with explanation of metaphor (Activity 4 and 5)
4. Posttest 1
5. Instruction with activity 6
6. Posttest 2

I. Pre-test:

In-class instruction to interdisciplinary teams:

1. Group formation: Please form teams of three such that no two members are from the same discipline.
2. Topic selection: Each of you must select three technical topics that are specific to your field of study. You must be able to explain these topics with confidence. These topics may be concepts or methods. For example, I would select Kanban system. As you notice, I have chosen a topic with which none of my group members are familiar.
3. Confirm ignorance: Ask your team members if they have heard of any of these topics before. If yes, you must replace them with topics they are unaware of.
4. You may take the next 2 minutes to select and confirm these topics after forming your groups.
5. (After 5 minutes) Now that you have selected the topics please write them down on the sheets given. Select one of the three topics.

6. You have now chosen one of the three topics. You have to explain this topic to your group members in not more than 5 minutes. You may just talk about the concept or draw to explain or both. This is up to you.
7. Now take 5 minutes to think about ways to explain the concept you have chosen. You may make rough notes in the sheet given.
8. (After 5 minutes) Now each of you must explain your concept to the other two. Immediately after each one's explanation, the other two will fill up two questionnaires provided. Please write down your names on the questionnaires.
9. (After all explanations are given and questionnaires complete) You must now evaluate if your group members were on the same page as you when you were explaining them. Guidelines will be provided to you to make these evaluations.

**Questionnaire 1**

| Question | Answer |
|---|---|
| Topic explained | |
| I could describe the concept before it was explained to the group | ○ Yes ○ No |
| He/she explained the concept well | ○ Strongly agree ○ Agree<br>○ Neutral<br>○ Strongly Disagree ○ Disagree |

**Questionnaire 2**

| |
|---|
| Summarize the topic in **2-3 sentences**. Mention the main and relevant points.<br><br>Topic name:<br><br>Summary: |

You must evaluate the summary from questionnaire 2 as per the guidelines in the rubric given to you. Encircle the relevant choices.

| | 1 | 2 | 3 |
|---|---|---|---|
| Vocabulary | Summary does not use the same or similar words you used | Summary uses some similar words | Summary mostly uses same and similar words |
| Accuracy in interpretation | There are deep inaccuracies about the topic content | There are minor inaccuracies about the topic content | Correct/accurate interpretation with no inaccuracies |
| Clarity | Does not mention the main point/concept of the topic | Incompletely mentions main point/concept of the topic | Clearly and completely mentions main point/concept |

The next activity will teach you to *generate* analogs:

For example:

Sun: Solar system :: Heart : _____ :: _____ : _____

In the above example, the relationship between the sun and the solar system must be mapped onto the target analogies to determine the unknown element in the target analogy (Heart: _____ ). Here the 'sun' is central to the solar system both in existence and physical layout. Without the sun's light and gravitational forces the planets of the solar system may not revolve around their orbits and remain a coherent solar system. Similarly, the heart is central to 'living' or 'circulatory system'. Now generate an analogy on the same lines as the previous analogies. Something like fuel: car.

**Activity 3**

Now fill in the blanks by generating elements of the target analogy and hence generating analogies on the same lines:

Gear: cogs (gear teeth) :: Team : _____ :: _____: Ingredients :: _____ : _____

Marketing: customer :: Cooking : _____ :: _____ : _____

Solution to activity:

Gear: cogs (gear teeth) :: Team : *team member functions/activities* :: *tasty dish*: Ingredients :: *Metaphor: ideas from different disciplines/functions*

Marketing: customer :: Cooking : *those who eat the food* :: *interview*: *panel of interviewees*

*Activity 4 - Activity to generate and apply metaphors:*

For example, concept: integration of ideas

Metaphor: mesh of ideas

Used in a sentence: The design of the new product was a mesh of ideas of the team members.

| Concept | Metaphor | Usage in sentence |
|---|---|---|
| Integration | Mesh, Bind, Tie, Build | The design of the new product was a mesh of ideas of the team members |
| Opportunity | | |
| Idea | Food/fuel, | |

Solution to activity:

| Concept | Metaphor | Usage in sentence |
|---|---|---|
| Integration | Mesh, Bind, Tie, Build | The design of the new product was a mesh of ideas of the team members |
| Opportunity | *Window, light, room* | *With such a packed plan I think we haven't closed all windows for surprise.* |
| Idea | Food/fuel, *spark* | *There was a spark in my mind that I would like to share* |

If you notice here, the concept is given a certain aspect/property by the metaphor. For example, the metaphor ‘mesh’ and ‘bind’, gives the aspect of fitting within one another. Here, this aspect is taken from the domain knowledge of gears and chemical bonding respectively. Similarly, the metaphor ‘tie’ hails from the domain of probably making knots and building comes from the construction domain. Here the metaphors ‘tie’ and ‘build’, gives the aspect of extending or building onto some basic foundation. The metaphor ‘food/fuel’ for ‘idea’ explains that ideas are needed for the mind to function in certain instances.

**Posttest 1**

1. Group formation: Please form into the same teams as earlier.
2. Topic selection: Pick one of the two topics you haven’t already used from the activity earlier.
3. You have now chosen one of the three topics. You have to explain this topic to your group members in not more than 5 minutes. You may just talk about the concept or draw to explain or both. You must remember to use analogies and metaphors while explaining this topic to your group members.
4. Now take 5 minutes to think about some analogies and metaphors, and ways to explain the concept you have chosen. You may make rough notes in the sheet given.
5. (After 5 minutes) Now each of you must explain your concept to the other two. Immediately after each one’s explanation, the other two will fill up two questionnaires provided. Please mention your names on the questionnaires.
6. (After all explanations are given and questionnaires complete) You must now evaluate if your group members were on the same page as you when you were explaining them. Guidelines will be provided to you to make these evaluations.

*Questionnaire 1*

| Question | Answer |
|---|---|
| Topic explained | |
| I could describe the concept before it was explained to the group | ○ Yes ○ No |
| He/she explained the concept well | ○ Strongly agree ○ Agree ○ Neutral ○ Strongly Disagree ○ Disagree |
| He/she used analogies and metaphors in the explanation | ○ Yes ○ No |
| When you think about the topic now do you think about any of the analogies and metaphors used to explain it | ○ Yes ○ No |
| The analogies and metaphors used helped me understand the topic better | ○ Strongly agree ○ Agree ○ Neutral ○ Strongly Disagree ○ Disagree |
| It would be easier to understand the topic without analogies or metaphors | ○ Strongly agree ○ Agree ○ Neutral ○ Strongly Disagree ○ Disagree |

*Questionnaire 2*

| |
|---|
| Summarize the topic in **2-3 sentences**. Mention the main and relevant points.<br><br>Topic name:<br><br>Summary: |

*Instructions to evaluate summary*

You must evaluate the summary from questionnaire 2 as per the guidelines in the rubric given to you. Encircle the relevant choices.

| | 1 | 2 | 3 |
|---|---|---|---|
| Vocabulary | Summary does not use the same or similar words you used | Summary uses some similar words | Summary mostly uses same and similar words |
| Accuracy in interpretation | There are deep inaccuracies about the topic content | There are minor inaccuracies about the topic content | Correct/accurate interpretation with no inaccuracies |
| Clarity | Does not mention the main point/concept of the topic | Incompletely mentions main point/concept of the topic | Clearly and completely mentions main point/concept |
| Use of analogy and metaphor | Summary did not mention any analogy or metaphor<br>Or<br>Summary mentions analogy and/or metaphor(s) that was not used in the explanation AND does not/incorrectly explains the concept | Summary mentions analogy and/or metaphor used in the explanation BUT does not explain concept correctly | Summary mentions analogy and/or metaphor(s) used in the explanation<br>Or<br>Summary mentions analogy and/or metaphor(s) that was not used in the explanation BUT correctly explains concept |

**Activity 6**

*Activity to retrieve, identify, select and generate effective analogies and metaphors:*

The objective of this activity is to help you generate analogies and metaphors that can be easily understood by your audience. The table given to you will specify the discipline/function of your audience. You must select analogies and metaphors from those disciplines/functions to explain the topic given to you. In case the audience discipline/function is unknown, it is good to generate similarities from a common discipline/function like basic science for an audience of engineers.

| Topic | Discipline/functions audience is familiar | Similarities | Analogy and metaphor |
|---|---|---|---|

| | with | | usage |
|---|---|---|---|
| Greenhouse effect | Engineers | Glass absorbs heat from the sun<br>Earth's atmosphere absorbs heat (infrared rays) from the sun<br>- glass is like atmosphere | Analogy:<br><br>Metaphor: |
| Design | Finance/accounting | | Analogy:<br><br>Metaphor: |

Solution to activity:

| Topic | Discipline/functions audience is familiar with | Similarities | Analogy and metaphor usage |
|---|---|---|---|
| Greenhouse effect | Engineers | Glass absorbs heat from the sun<br>Earth's atmosphere absorbs heat (infrared rays) from the sun<br>- greenhouse is like earth<br>- glass is like atmosphere | Analogy: The earth's atmosphere is like glass because of which it can contain some of sun's heat rays<br>Metaphor: The glass effect of the atmosphere contains some of sun's heat. |
| Design | Finance/accounting | -Design constraints are like the budget<br>-The criteria to optimize costs are like trying to make the most innovative product but without going beyond the constraints of time, etc. | Analogy: Design constraints are like the budget which should not be exceeded.<br>Metaphor: Design budgets the resources available. |

# Appendix E

## IRB letter of approval

VirginiaTech

**Office of Research Compliance**
Institutional Review Board
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, Virginia 24061
540/231-4991 Fax 540/231-0959
e-mail moored@vt.edu
*www.irb.vt.edu*

FWA00000572( expires 1/20/2010)
IRB # is IRB00000667

DATE: January 14, 2008

MEMORANDUM

TO: Elizabeth McNair
Akshi Kakar

Grant Compared 1/11/08

Approval date: 1/14/2008
Continuing Review Due Date:12/30/2008
Expiration Date: 1/13/2009

FROM: David M. Moore

SUBJECT: **IRB Expedited Approval:** "Teaching Analogies and Metaphors to Enhance Communication in Interdisciplinary and Cross-Functional Groups", OSP #477533, IRB # 08-003

This memo is regarding the above-mentioned protocol. The proposed research is eligible for expedited review according to the specifications authorized by 45 CFR 46.110 and 21 CFR 56.110. As Chair of the Virginia Tech Institutional Review Board, I have granted approval to the study for a period of 12 months, effective January 14, 2008.

As an investigator of human subjects, your responsibilities include the following:

1. Report promptly proposed changes in previously approved human subject research activities to the IRB, including changes to your study forms, procedures and investigators, regardless of how minor. The proposed changes must not be initiated without IRB review and approval, except where necessary to eliminate apparent immediate hazards to the subjects.
2. Report promptly to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.
3. Report promptly to the IRB of the study's closing (i.e., data collecting and data analysis complete at Virginia Tech). If the study is to continue past the expiration date (listed above), investigators must submit a request for continuing review prior to the continuing review due date (listed above). It is the researcher's responsibility to obtained re-approval from the IRB before the study's expiration date.
4. If re-approval is not obtained (unless the study has been reported to the IRB as closed) prior to the expiration date, all activities involving human subjects and data analysis must cease immediately, except where necessary to eliminate apparent immediate hazards to the subjects.

**Important:**
If you are conducting **federally funded non-exempt research**, this approval letter must state that the IRB has compared the OSP grant application and IRB application and found the documents to be consistent. Otherwise, this approval letter is invalid for OSP to release funds. Visit our website at http://www.irb.vt.edu/pages/newstudy.htm#OSP for further information.

As indicated on the IRB application, this study is receiving federal funds. The approved IRB application has been compared to the OSP proposal listed above and found to be consistent. Funds involving procedures relating to human subjects may be released. Visit our website at www.irb.vt.edu for further information

cc: File
OSP

*Invent the Future*

VIRGINIA POLYTECHNIC INSTITUTE UNIVERSITY AND STATE UNIVERSITY

*An equal opportunity, affirmative action institution*

**Amended letter of approval**

VirginiaTech

**Office of Research Compliance**
Institutional Review Board
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, Virginia 24061
540/231-4991 Fax 540/231-0959
e-mail moored@vt.edu
*www.irb.vt.edu*
FWA00000572( expires 1/20/2010)
IRB # is IRB00000667

DATE: March 21, 2008

MEMORANDUM

TO: Elizabeth McNair
Akshi Kakar

Approval date: 1/14/2008
Continuing Review Due Date:12/30/2008
Expiration Date: 1/13/2009

FROM: David M. Moore

SUBJECT: **IRB Amendment 1 Approval:** "Enhancing Group Cognitive and Behavioral Characteristics", OSP #477533, IRB # 08-003

This memo is regarding the above referenced protocol which was previously granted approval by the IRB on January 14, 2008. You subsequently requested permission to amend your IRB application. Since the requested amendment is nonsubstantive in nature, I, as Chair of the Virginia Tech Institutional Review Board, have granted approval for requested protocol amendment, effective as of March 21, 2008. The anniversary date will remain the same as the original approval date.

As an investigator of human subjects, your responsibilities include the following:

1. Report promptly proposed changes in previously approved human subject research activities to the IRB, including changes to your study forms, procedures and investigators, regardless of how minor. The proposed changes must not be initiated without IRB review and approval, except where necessary to eliminate apparent immediate hazards to the subjects.
2. Report promptly to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.
3. Report promptly to the IRB of the study's closing (i.e., data collecting and data analysis complete at Virginia Tech). If the study is to continue past the expiration date (listed above), investigators must submit a request for continuing review prior to the continuing review due date (listed above). It is the researcher's responsibility to obtained re-approval from the IRB before the study's expiration date.
4. If re-approval is not obtained (unless the study has been reported to the IRB as closed) prior to the expiration date, all activities involving human subjects and data analysis must cease immediately, except where necessary to eliminate apparent immediate hazards to the subjects.

As indicated on the IRB application, this study is receiving federal funds. The approved IRB application has been compared to the OSP proposal listed above and found to be consistent. Funds involving procedures relating to human subjects may be released. Visit our website at www.irb.vt.edu for further information

cc: File

**Informed consent form**

**Virginia Polytechnic Institute and State University**

**Project Title:** Teaching analogies and metaphors to enhance communication in interdisciplinary and cross-functional groups

**Investigators:** *Akshi Kakar, Industrial and Systems Engineering; Lisa McNair, Engineering Education; Brian M. Kleiner, Industrial and Systems Engineering*

**Research Consent Form**
You are being asked to be a volunteer in a research study.

**I. Purpose of this Research:**
The purpose of this study is:

- To develop and validate an instructional tool for its effectiveness in enhancing communication across disciplines and functions.

**II. Procedures:**
If you decide to be in this study, your part will involve one or more of the following activities:

- Participating in an observed class. The class will be audio-taped and the investigator conducting the session will also take notes throughout the session.
- You will also be asked to participate in several communication activities. The activities for this study will count toward your participation grade in the course, but your participation as a subject in the research study is entirely voluntary.

**III. Risks/Discomforts**
The following risks/discomforts may occur as a result of your participation in this study:

- The risks involved are no greater than those involved in daily activities. Your decision to participate or not participate in this study will not be revealed to anyone other than the two VT investigators who are not instructors in the course (Akshi Kakar and Brian Kleiner).

**IV. Benefits**
The following benefits to you are possible as a result of being in this study:

- You may learn from the instruction provided to you and hopefully be able to communicate better by consciously using these communication tools.

**IV. Extent of Anonymity and Confidentiality**

The following procedures will be followed to keep your personal information confidential in this study: The data that is collected about you will be kept private to the extent allowed by law. To protect your privacy, your records will be kept under a code number rather than by name. Your records will be kept in locked files and only study staff will be allowed to look at them. Your name and any other fact that might point to you will not appear when results of this study are presented or published.

The audio tapes resulting from this study will be converted into written transcripts with all identifying names and comments removed. Once the transcript is completed the tapes will be erased/destroyed.

To make sure that this research is being carried out in the proper way, the Virginia Tech IRB will review study records. The Office of Human Research Protections may also look at study records.

**V. Costs to You**

- There are no costs to you.

**VI. Subject Rights**

- Your participation in this study is voluntary. You do not have to be in this study if you don't want to be.
- You have the right to change your mind and leave the study at any time without giving any reason, and without penalty.
- Any new information that may make you change your mind about being in this study will be given to you.
- You will be given a copy of this consent form to keep.
- You do not waive any of your legal rights by signing this consent form.

**VII. Questions about the Study or Your Rights as a Research Subject**

- If you have any questions about the study, you may contact Akshi Kakar, at telephone (404-713-0433) or Dr. Lisa McNair, at telephone (540-231-1144).
- If you have any questions about your rights as a research subject, you may contact Mr. David Moore at 540-231-4358.

**VIII. Approval of Research**

This research project has been approved, as required, by the Institutional Review Board for Research Involving Human Subjects at Virginia Polytechnic Institute and State University.

_____ _____

IRB Approval Date Approval Expiration Date

**IX. Subject's Responsibilities**

Forum (circle all that apply): Observation Materials from activities Focus Group

I voluntarily agree to participate in this study. I have the following responsibilities:

- During the course of the activities, answer, as honestly as possible, questions concerning clarity and understanding in communication.

**X. Subject's Permission**
I have read and understand the Informed Consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:

_____
Subject Name (please print)

_____ Date: _____
Subject signature

Should I have any questions about this research or its conduct, I may contact:

Akshi Kakar, Principal Investigator

Lisa McNair, Faculty Advisor
540-231-1144, lmcnair@vt.edu (Investigator)

O. Hayden Griffin, 540-231-6555, griffin@vt.edu
Chair, Department of Engineering Education

David M. Moore, 540-231-4991, moored@vt.edu
Chair, IRB
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