

A COMPUTER-BASED TRAINING COURSE FOR ASSESSING  
MATERIAL SAFETY DATA SHEET COMPREHENSION

by

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(ABSTRACT)

This thesis research tested the utility of a quantitative measure of idea progression ( $B_1$ ) in a computer-based training environment. Anderson (1971) only studied the different levels of the metric by simply rearranging sentences. In this experiment, however, careful rephrasing of a text created three statistically different training programs with  $B_1$  averages of 0.31, 0.39, and 0.48 from instructional design, human-computer interaction, and human information processing guidelines. Three groups of industrial subjects ( $n = 8$ ) were trained and tested to see which level maximizes worker comprehension of the chemical hazard concepts found in the Occupational Safety and Health Administration's (OSHA) Material Safety Data Sheet (MSDS) Form 174. It was expected that subjects who received medium levels of complexity would show the highest posttest scores; however, no significant differences were detected ( $p > 0.05$ ). The negative results and corresponding small effect size are discussed along with future research suggestions.

## ACKNOWLEDGEMENT

I would like to thank Sandra, my wife, for her continual support and love.

1 The heavens declare the glory of God; and the firmament sheweth his handywork.

2 Day unto day uttereth speech, and night unto night sheweth knowledge.

3 There is no speech nor language, where their voice is not heard.

4 Their line is gone out through all the earth, and their words to the end of the world. In them hath he set a tabernacle for the sun,

5 Which is as a bridegroom coming out of his chamber, and rejoiceth as a strong man to run a race.

6 His going forth is from the end of the heaven, and his circuit unto the ends of it: and there is nothing hid from the heat thereof.

7 The law of the LORD is perfect, converting the soul: the testimony of the LORD is sure, making wise the simple.

8 The statutes of the LORD are right, rejoicing the heart: the commandment of the LORD is pure, enlightening the eyes.

9 The fear of the LORD is clean, enduring for ever: the judgments of the LORD are true and righteous altogether.

10 More to be desired are they than gold, yea, than much fine gold: sweeter also than honey and the honeycomb.

11 Moreover by them is thy servant warned: and in keeping of them there is great reward.

12 Who can understand his errors? cleanse thou me from secret faults.

13 Keep back thy servant also from presumptuous sins; let them not have dominion over me: then shall I be upright, and I shall be innocent from the great transgression.

14 Let the words of my mouth, and the meditation of my heart, be acceptable in thy sight, O LORD, my strength, and my redeemer.

--Psalm 19

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# INTRODUCTION

## Background of Problem

Hazard Communication Standard. Since passage of the Williams-Steiger Occupational Safety and Health Act [OSHA] of 1970 and the OSHA Hazard Communication Standard (29 CFR 1910.1200), the Federal Government has placed many mandatory requirements on American industry to ensure “so far as possible every working man and woman in the nation safe and healthful working conditions and to preserve our human resources” (Hammer, 1985, p. 51). The Hazard Communication Standard (HCS), in particular, “was developed to ensure that employers evaluate hazards of chemicals and to ascertain that employees understand these hazards. Although the basis for the program has been described as being the Material Safety Data Sheet (MSDS), transmittal of the hazard information through training has become known as the key link, the reinforcer of the standard” (Capuano, 1986, p. 32).

The performance-based Hazard Communication Standard covers over six million workplaces and became effective in May, 1986 with the stated purpose “that employees have both a need and a right to know the hazards and identities of the chemicals they are exposed to when working. They also need to know what protective measures are available to prevent adverse effects from occurring. The HCS is designed to provide employees with the information they need” (Hazard Communication Guidelines for Compliance, Occupational Safety and Health Administration, 1990, OSHA 3111, p.1). The HCS provides only a general framework for compliance with the goal to reduce the incidence of chemical source illnesses and

injuries specifically through educating workers about chemical hazards. Employers are told that “If your program works, you and your workers will better understand the chemical hazards within the workplace” (ibid., p. 11).

The Hazard Communication Standard stipulates that “employers at facilities where hazardous chemicals are handled have five obligations:

1. They must identify and list hazardous materials in the their workplace
2. They must obtain an MSDS for each hazardous chemical and assure that all containers are properly labeled
3. They must develop and implement a written hazard communication program
4. They must communicate hazard information to their employees through the use of labels, MSDSs, and formal training programs
5. The information developed, including the list of chemicals, MSDSs and the written program must be made accessible to employees at all times” (Dickson 1990, p. 97).

However, it is not enough just to comply with regulations to reduce workplace hazards. Industry needs to adopt the systems safety approach to achieve and maintain “a state such that each person will live and work under conditions in which hazards are known and controlled to an acceptable level of potential harm” (Roland and Moriarty, 1983, p. 13). There are four steps in hazard control, including “design for acceptable hazard, safety devices, warning devices, and procedures and training” (ibid., pp. 188-190). The MSDS can serve as a warning device and provides the basis for training programs.

The MSDS was developed and is currently used as the main vehicle for communicating chemical hazard information. This information is presented under a performance standard. When a performance-based standard requires training as a

hazard control mechanism, it creates additional burdens and opportunities for the employer. Since only the goal of training workers in chemical awareness and safety is specified, the employer can not follow the compliance route of issuing rules to the workers; the employer must think it through. This flexibility in compliance, however, can create an opportunity for the safety professional to tailor a hazard control program to the actual needs of the employer and not those of Washington lawmakers and regulators. This is especially true for the Hazard Communication Standard.

Fundamentally, however, the MSDS is “the key source of information on which to build a hazard-communication program.” (Olsen, 1987, p. 110). The following defines a chemical hazard as “a material that has one or more of the following characteristics:

1. Has a flash point below 140°F, closed cup, or is subject to spontaneous heating
2. Has a threshold limit value below 500 ppm for gases and vapors, below 500 mg/m<sup>3</sup> for fumes, and below 25 mppcf [million particles per cubic foot] for dust
3. A single dose oral  $LD_{50}$  [ $LD_{50}$  means a lethal dose to 50% of a population] below 500 mg/kg
4. Is subject to polymerization with the release of large amounts of energy
5. Is a strong oxidizing or reducing agent
6. Causes first-degree burns to skin in short time exposure, or is systematically toxic by skin contact

7. In the course of normal operations, may produce dusts, gases, fumes, vapors, mist or smokes which have one or more of the above characteristics”(ibid., p. 107).

**MSDS Form 174.** The following describes the eight sections of the MSDS Form 174.

Section I--Manufacturer's Information provides the identity of the chemical, the manufacturer's name, address, an emergency telephone number, a non-emergency telephone number, the date the MSDS was prepared, and an optional place for the signature of the preparer. This section lists the necessary information needed to contact the chemical's manufacturer either in writing or by phone for clarification of concerns not specifically addressed at the local use site.

Section II--Hazardous Ingredients/Identity Information lists the percent composition and the names of the hazardous components of the chemical. Both common and precise chemical names may be listed including the Chemical Abstract Service number (CAS #) for each component. Other important information includes current regulatory and suggested short-term and long-term exposure limits.

Section III--Physical and Chemical Characteristics lists the chemicals' boiling point, vapor pressure, vapor density, specific gravity, melting point, evaporation rate, solubility in water, and appearance and odor.

Section IV--Fire and Explosion Hazard Data lists the flash point, flammable limits, extinguishing media, special fire fighting procedures, and unusual fire and explosion hazards.

Section V--Reactivity Data tells whether the chemical is unstable or stable and what conditions or materials to avoid, and whether or not hazardous polymerization may occur and what conditions to avoid.

Section VI--Health Hazard Data lists the routes of entry for the chemical, acute and chronic health hazards, carcinogenicity, signs and symptoms of exposure, medical conditions generally aggravated by exposure, and emergency and first aid procedures.

Section VII--Precautions for Safe Handling and Use lists the steps to take in case the material is released or spilled, waste disposal method, precautions in handling and storing, and any other precautions.

Section VIII--Control Measures lists the type of respiratory protection needed, ventilation type, personal protective equipment (PPE), and work and hygienic practices.

**MSDS history.** The development of the MSDS poses inherent comprehension problems for the MSDS content. Historically, “MSDSs are not new inventions. In fact, their history goes back over 30 years to the mid-1950s. At that time, MSDSs were not called MSDSs at all, but rather chemical safety data sheets. These data sheets were not written by the chemical’s manufacturer but rather by the Manufacturing Chemists Association, the predecessor to today’s Chemical Manufacturers Association” (Eisner, 1991, p. 6).

The original authors, then, used their own professional jargon and created a communication barrier. “This is not to say that technical language was all that bad. Keep in mind that these documents were intended for use by scientists, not by lay people and certainly not by workers” (Eisner, 1991, p. 6). However, the current MSDS preserves much of the chemical safety data sheets’ language. Also, industrial workers who not only have trouble with scientific language, but also with chemical hazard concepts must use them.

Chemical exposure risks. The consequences of workers not fully understanding the risks and precautions associated with chemical usage may be severe. “Chemical exposure may cause or contribute to many serious health problems, such as heart and kidney ailments, lung damage, cancer, sterility, burns and rashes. Some chemicals may also be safety hazards and have the potential to cause fires and explosions and other serious accidents” (Olsen, 1987, p. 107). Moreover, the potential for accidents involving hazardous materials is great. “Virtually all employees within the American labor force occasionally come in contact with substances that could be considered hazardous if improperly used. For many workers, contact with hazardous chemical is a daily requirement of the job. Furthermore, as technology advances, the list of potentially hazardous substances and the opportunities for worker exposure are increasing at a rapid rate. For these reasons, easy access to useful, accurate hazard information becomes increasingly important” (Ensminger, Lu, and Oen, 1988, p. 267).

These risks and problems can be avoided with an effective hazardous communication training program benefiting both workers and companies. “A worker who understands the hazards of a chemical is more likely to improve work practices, use personal protective equipment when necessary, and take other precautionary measures when handling the chemical to control exposure to it” (Kmetz, 1990, p. 33). The training must then provide, “instruction on how to read labels and the MSDS, an explanation of the health and physical hazards of chemicals, protection measures employees should take to prevent injuries and illnesses from chemical exposure, information on storage and handling requirements, engineering controls and the selection of personal protective equipment, and methods to detect the

presence of the chemical in the workplace” (Dickson, 1990, p. 37). In sum, West (1991, p. 13) observes that:

The basic assumption is that risk of harm or injury will be significantly reduced by means of communicating key information about the hazards involved. However, although this seems to be a reasonable assumption, the results have not as yet been demonstrated. In fact, too much detailed information may tend to clutter the impact of the truly important issues, particularly among workers with limited technical backgrounds and in emergency situations. Thus, there is a real challenge in the industry to see that the right information, but not too detailed, is included on the MSDS, and that a real worker education program is developed and continued in order to demonstrate the basic assumption.

**Training.** Given this challenge, how should the safety professional exercise the “freedom” under this performance-based standard to best implement the required training in the workplace? A recommended method (Goldstein, 1993) is the systems training approach. It provides tools to develop training programs that document good faith effort in compliance.

The safety professional views hazards as implied threats with the potential to do harm. Formally, a hazard may be defined as “A potential condition, or set of conditions, either internal and/or external to a system, product, facility, or operation, which, when activated by a stimulus, transforms the hazard into a real condition, or series of event which culminate in a loss (an accident)” (Roland and Moriarty, 1983, p.6).

Roland and Moriarty (1983, p. 71) assert that “training programs that are appropriate to the users is a necessity.” This supports the need for instructional

design methodology to specify the problem and potential solutions. The author's experience with the HCS confirms West's assumption that the problem centers around teaching employees the content of the MSDS and how to use it.

The solution, then, lies in rigorous experimentation to determine the proper methods to teach employees how to use the MSDS. Such experiments should be designed for employees to perform Operation Hazard Analyses (OHA) which focus "on hazards resulting from tasks, activities, or operating system functions that occur as the system is stored, transported, or exercised" (ibid., p. 209). However, based upon the author's experience teaching employees, there are barriers to effective utilization of the MSDS as an OHA. As previously discussed, some of the problems include the actual MSDS "interface" and terminology gaps. The systems approach to training provides the tools to overcome these barriers.

## **Related Literature**

A variety of theories can be interpreted and used to justify the purpose of any training program. According to psychologist J. J. Gibson, "Learning requires not only that we make the appropriate reactions but also that we be sensitive to the appropriate stimuli. An important aspect of education, or of any kind of special training, military, industrial, or professional, is an increasing ability to discriminate and identify things" (Gibson, 1954, p. 4). In this case, types of chemical hazards need to be identified using the MSDS.

The following text cites the major theories that provide the background for this research. The developers are listed, and the essence of the theories are discussed along with how each is applicable to the thesis.

**Elaboration Theory.** Elaboration Theory (Reigeluth, 1983, 1987) presents macro sequencing strategies as consistent prescriptions that help the instructional designer create the means that trainees use to demonstrate material mastery. There are three general types of content: principles, procedures and concepts. Each type can serve as epitomes, or the essential components of the course material that the designer wishes to incorporate.

A principle is “a change relationship. . . between a change in one thing and a change in something else” (Reigeluth, 1983, p. 343). A procedure is “a set of actions that are intended to achieve an end” (ibid.). Finally, a concept is “a set of objects, events, or symbols that have certain characteristics in common” (ibid.). The instructional designer will then incorporate different strategies and develop sub-goals for each type of content to further elaborate on the epitome.

The content type for this research is principle. Specifically, the principle that workers understand the kinds of chemical hazard risks associated with a particular chemical, the routes of chemical entry, and how this information is presented in the MSDS Form 174. This is in keeping with the fundamental HCS goal of reducing chemical source illness and injury. However, a complete HCS training curriculum encompasses all three forms of content.

Elaboration Theory uses three different kinds of elaborative sequences and epitomizing for the simple-to-complex sequencing of ideas. Epitomizing means that only a few of the ideas to be taught are presented and that the ideas are presented concretely. This does not mean to preview all the main ideas in a course, but to present “a few fundamental and representative ideas that convey the essence of the entire content” at “an application level, complete with examples and practice that enable the learner to relate it to previous knowledge and experience.” Reigeluth

(1983, p. 343). The use of an epitome is exactly what is required for a corporate training program. Presenting the ideas so that the trainees will be able to use each of them to “predict or explain novel cases” maximizes positive transfer from the training environment to the workplace environment. It also has the added advantage of maximizing corporate training resources of time and availability constraints. The trainees have the opportunity to acquire useful skills. All of this, of course, rests upon the assumption that appropriate task analyses were completed before the development of the training program. Finally, elaboration theory is considered to be one of the most prescriptive, and integrates the work of many well-known instructional designers, including Gagné and Briggs.

**Component Display Theory.** In contrast to Elaboration Theory, Component Display Theory or CDT (Merrill, 1983, 1987) presents micro sequencing strategies for a single instruction event inside the larger framework that Elaboration Theory provides. CDT elaborates and supports the training epitome on a micro-level. For this experiment, the training epitome was understanding exposure risks of chemicals in the workplace. Based on pretesting results, workers consistently ranked sections II and V of the MSDS as the most difficult to understand. Since, comprehension of these sections depends heavily upon the concept of dose rate, it forms the basis of the MSDS training. Dose rate is operationally defined as exposure to a certain amount of a hazard over a certain amount of time. CDT then provides a series of prescriptive matrices to determine how to present, allow practice of, and test the trainees’ performance of the training content. In the experiment, CDT provides such information on a screen-by-screen basis.

**Text Progression Density.** Text progression density (Anderson, 1969, 1971) is a quantitative measure of the repetition of ideas and rate of introduction of new

ideas in a text. This quantitative metric has not been widely used and neither its developer (Anderson, personal communications, 1993) nor the author is aware of any published computer-based training program applications. However, this metric lends itself well to assessing the effectiveness of a training program. Given the dearth of quantitative guidelines for computer-based applications and instructional design as a whole, the text progression density algorithm may serve as a simple, but elegant way to predict trainee preference and comprehension of instructional materials.

Text progression density is measured in the following way. In matrix format, columns represent each sentence of the training course content and rows represent each relevant concept. This array shows the frequency with which concepts are contained in each sentence.

By comparing column 1 with column 2, then column 2 with column 3, and so on, commonality between each sentence can be determined. The fundamental coefficient of kinetic structure “is a quantitative expression of the degree of verbal commonality in pairs of discourse units” (Anderson, 1971, p. 13) Commonality coefficients ( $B_1$ ) are calculated by the following formula:

$$B_1 = \frac{n_1}{n_0 + n_1}$$

where  $n_1$  represents the number of times a common concept appears in each pair of statements and  $n_0$  is the number of uncommon concepts. Commonality provides a measure of the extent to which content in the progression of sentences is related. Hence, the term “progression density” aptly describes the degree of concept similarity and relatedness throughout the text.

In contrast, more traditional metrics of text difficulty such as grade level or the Gunning Fog Index only consider the number of words and syllables in the text

and not the relationship of concepts or ideas between sentences. For example, to determine the Gunning Fog Index (Gunning, 1952, pp. 36-37) :

1. count the number of words in successive sentences,
2. count the number of words of three syllables or more per 100 words, and
3. total the counts from 1 and 2 and multiply by 0.4.

**Inverted U-shaped performance curves.** The Yerkes-Dodson performance curves (Wickens, 1992, p. 414) indicate that people perform best under moderate stimulation. Thus, there are three complexity levels of content used in the experiment. The performance curve exhibits an inverted U-shape, indicating a peak in performance. Since this experiment focuses on only one training task of maximizing MSDS comprehension with respect to dose rate, there is only one hypothetical performance curve for the dependent measures. Wickens (1992, p. 415) notes that

One of the problematic characteristics of the Yerkes-Dodson law is that it is difficult if not impossible to know, a priori, where the optimum level of arousal is for a particular task and, hence, whether the introduction of a stressor will lead to an initial increase or decrease in task performance.

## **Purpose**

This thesis investigates the potential differences in trainee speed and accuracy performance due to the “stressor” of text progression density. The purpose is to show that Anderson’s (1969, 1971) text progression density can predict the effectiveness of computer-based training for workers about the chemical hazard information found in Material Safety Data Sheets. This metric could help industry comply with both the letter and spirit of the Hazard Communication Standard (29

CFR 1910.1200). The idea originated from the author's work as a safety intern, in which he developed and administered a Hazard Communication Training Program for a Bristol, Virginia manufacturer. A quantitative measure of idea progression serves as an objective measure of the depth or complexity of training content. The model incorporates instructional design, human-computer interaction, and human information processing guidelines to determine quantitatively the information complexity that maximizes worker comprehension of MSDS the chemical hazard concepts found in the OSHA Material Safety Data Sheet Form 174.

Members of the industrial population are the target group for this research. It was necessary, then, to include subjects who work in an industrial environment under the Hazard Communication Standard regulations. Such selection procedures enhance the face validity and the external validity of the experiment.

## **Hypotheses**

This research was conducted to investigate three specific hypotheses.

1. Trainee comprehension rates, as measured by a posttest, will exhibit an inverted U-shaped curve across content complexity levels.
2. A mid-range of complexity will produce higher comprehension than either a low or high amount of complexity.
3. Independently of the initial level of training content complexity, all trainees will recommend the mid-range complexity level as the best for understanding chemical hazard concepts.

## METHOD

### Experimental Design

**Independent variable.** The independent variable is content complexity as measured by Anderson's (1969, 1971)  $B_1$  algorithm. Subjects were randomly assigned to one of three complexity levels for the computer-based training. The  $B_1$  values for the Low, Mid, and High levels were, respectively, 0.31, 0.39, and 0.48.

**Dependent variable.** The training experiment has four parts--computer-based training, posttest, MSDS rating, and  $B_1$  level comparisons. The dependent variable for the computer-based training is reading speed measured in words per minute (WPM). For the posttest, the dependent measures are performance in percentage correct (P), the time to answer the posttest questions (QT), the time to rate each posttest question for difficulty (RT), and the difficulty rating for each question (D). For the MSDS rating, the dependent measures are reading speed (WPM) and the section difficulty rating (D). For the  $B_1$  level comparisons, subjects read excerpts from each complexity level in counter-balanced order. The dependent measures are reading speeds (WPM) and difficulty measures (D).

**Power.** Keppel (1991, p. 72) warns against low powered experiments; however, to achieve high power levels the sample size may "seem alarmingly large to most seasoned researchers." This is especially true for small effect sizes. But, to date, studies involving Anderson's  $B_1$  metric have relatively large effect sizes.

Although the power of the test is an important consideration, few studies directly report their power so it must be calculated indirectly. Simmon's (1977)

training study for microscope usage is similar in format and structure and has  $B_1$  averages 0.25 and 0.47 that approximate the range of values used in this experiment. Following Keppell's (1991, pp. 86-89) post hoc power analysis method, the power for her microscope experiment's Test of Multiple Choice Questions was calculated as greater than 99% with an effect size  $f = 0.834$ . This effect size is much greater than what Cohen (1977) would term a large effect.

A power analysis for one-way ANOVAs determined the number for replications for this experiment. Using Cohen's (1977) power tables ( $u = 2$ ,  $\alpha = 0.05$ , and  $f = 0.8$ ) a sample size of 8 yields more than 92% power.

### **Instructional Task and Content**

A distinguishing feature of this research is the methodology used to create the three levels of the independent variable. In previous research with Anderson's  $B_1$  metric, the different values used were created by rearranging the sentences. Here, development adhered to instructional design guidelines and the systems training approach.

A complete HCS training curriculum explains labeling, MSDSs, the Right-to-Know law, and a company's written safety plan. Focusing just on MSDSs, however, avoids performance deficits from other parts of the HCS curriculum. There are many problems with MSDSs as previously stated so this is, itself, a broad area. But to conduct research on this topic, the focus must be even narrower. The training goal for this experiment is that workers understand the kinds of chemical hazard risks associated with a chemical, routes of chemical entry, and how chemicals are presented in the MSDS Form 174.

Both Elaboration Theory and Component Display Theory (CDT) were used to develop and structure the training course. The epitome is risk, and the supporting concepts include: types of risk (to people, property and environment), reducing and/or eliminating the risk of airborne chemical exposure (to people), and MSDS Sections II, III, VI and VIII information. Figure 1 diagrams the training structure.

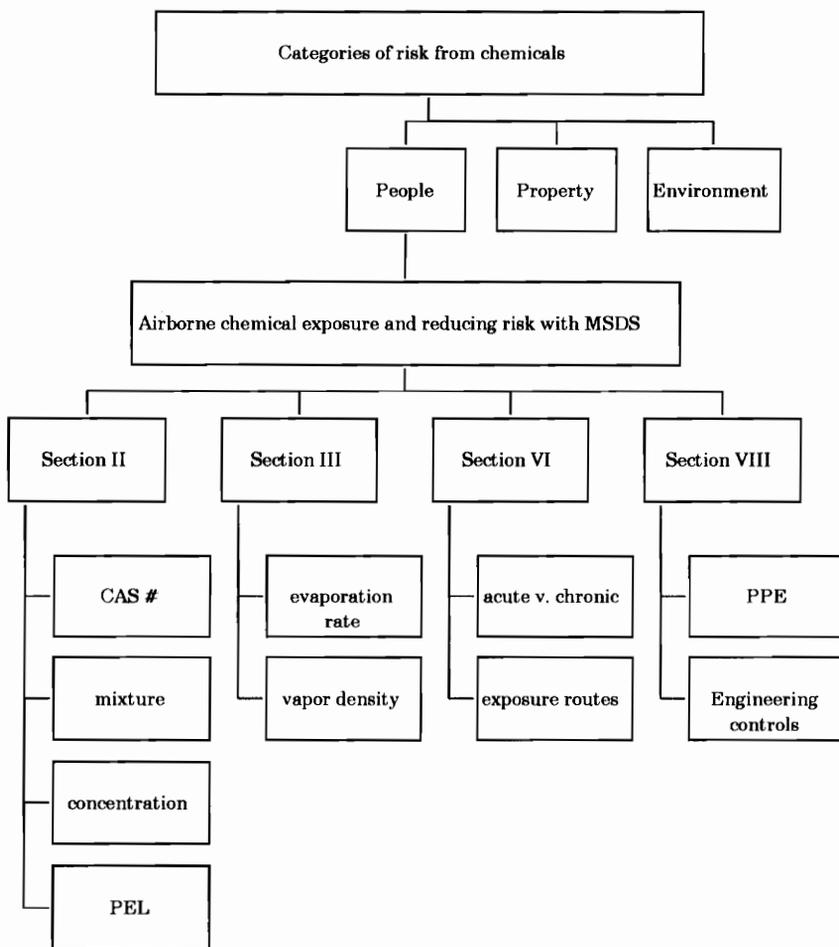


Figure 1. *Instructional Design Schematic.*

This core content was then modified to produce each level of the independent variable. Each MSDS section material was analyzed using the algorithm for calculating  $B_1$ . Appendix 10 provides the Microsoft Word macros used to track key words and develop each level of the training program. The three text versions were modified until a one-way ANOVA on sub-section average  $B_1$  values for each version were statistically different ( $p < 0.001$ ). A series of t-tests ( $\alpha = 0.05$ ) for paired two-sample means were then performed since there was an overall difference. The t-tests revealed differences at each section between each of the three levels: Low v. Mid ( $p < 0.001$ ), Low v. High ( $p < 0.001$ ), and Mid v. High ( $p < 0.001$ ).

It was not possible to create a coherent text that would both adhere to proper instructional design principles and have  $B_1$  values ranging much beyond those planned. Figure 2 shows a sample of the three different versions of the training program.

In contrast, more traditional measures of a text show few differences between the three versions of the training course. For example, the Gunning Fog Indices for the L, M, and H  $B_1$  values are, respectively, 13.7, 13.8, and 13.8. See Table 1 for a complete list of reading metric comparisons.

### Low $B_1 = 0.31$

In order for you to better understand the significance of a chemical concentration, let's review some chemistry. Concentration refers to how much of a chemical is dissolved into a mixture. Whether or not a chemical dissolves depends on its physical state. There are three states of matter, solid, liquid or gas.

When a material, such as a gas dissolves, it undergoes another type of physical change; one material physically moves inside and disperses into another. The result is a mixture. It is important to remember that a chemical's composition and properties may stay the same even when it is dissolved in something else. Sometimes, however, when chemicals mix, new chemicals may be formed that present additional health hazards. The more of a chemical that is dissolved in a given amount of material, such as water, the greater the risks associated with that mixture. Also, different chemicals dissolve at different speeds. Dissolving occurs fastest for gases, which can make airborne exposure a serious health threat.

### Mid $B_1 = 0.39$

In order for you to better understand the significance of a chemical concentration, let's review some chemistry. Concentration refers to how much of a chemical is dissolved into another. Whether or not a chemical dissolves depends on its physical state and other properties. There are three states of matter. The states are solid, liquid or gas. Let's use water as an example of these states. Water can be a solid (ice), a liquid, or a gas (steam or vapor).

When a material, such as a gas dissolves, it undergoes another type of physical change. One material physically moves inside and disperses into another. The result is a chemical mixture. It is important to remember that a chemical's composition and properties may stay the same even when it is dissolved in something else. Sometimes, however, when chemicals mix, new chemicals may be formed that present additional health hazards. The more of a chemical that is dissolved in a given amount of material, such as water, the greater the risks associated with that mixture. Also, different chemicals dissolve or mix at different speeds. Dissolving occurs at the fastest speed for gases. This can make airborne exposure to chemicals a serious health threat.

### High $B_1 = 0.48$

In order for you to better understand the significance of a chemical concentration, let's review some chemistry. Concentration refers to how much of a chemical is dissolved into another. Whether or not a chemical dissolves depends on its physical state and other properties. There are three states of matter. The states are solid, liquid or gas. Let's use water as an example of these states of solid, liquid, or gas. Water can be a solid (ice), a liquid, or a gas (steam or vapor).

When a material, such as a gas dissolves, it undergoes another type of physical change. One material physically moves inside and disperses into another. The result is a chemical mixture. It is important to remember that a chemical's composition and properties may stay the same even when it is dissolved in something else. Sometimes, however, when chemicals mix, new chemicals with new properties may be formed that present additional health hazards. The more of a chemical that is dissolved in a given amount of material, such as water, the greater the risks associated with that mixture. Also, different chemicals dissolve or mix at different speeds. Chemical mixing occurs at the fastest speed between gases. This mixing can make airborne exposure to chemicals a serious health threat.

Figure 2. *Samples from each training version.*

TABLE 1

## Traditional text metrics

	Training version		
	Low $B_1 = 0.31$	Mid $B_1 = 0.39$	High $B_1 = 0.48$
Flesch Reading Ease	46.6	46.1	47.0
Flesch Grade Level	13.5	13.6	13.5
Flesch-Kincaid	10.4	10.6	10.5
Gunning Fog Index	13.7	13.8	13.8
Number of words	1804	1881	2048
Number of paragraphs	37	29	33
Number of sentences	116	120	130
Sentences/paragraph average	4.3	4.1	3.9
Words/sentence average	15.6	15.7	15.8
Characters/word average	5.0	5.0	4.9

## **Formative Evaluation**

After Institutional Review Board (IRB) approval, formative evaluation of content was conducted. Three subjects assessed the content, interface, and testing methods before final data collection of the experiment. These subjects completed training, testing, and de-briefing within approximately one hour and fifteen minutes.

**Content.** Subjects evaluated the training materials for readability, understandability, and typographical errors. All content was reviewed favorably.

**Interface.** Subjects viewed the instructional material presented in a HyperCard stack with text ranging from 5 to 12 lines per card. All subjects preferred cards with fewer lines of text. They felt more comfortable, less rushed, and better able to absorb the information. After incorporating their suggestions, the final card text ranged from 4 to 9 lines per screen.

Analogous to the concern over the number of lines per computer screen was the amount of text per page on the posttest. Subjects said they were intimidated and anxious when they viewed a full page of text. Thus, the posttest was re-formatted with approximately two inches of white (blank) space at the bottom of each page.

**Testing methods.** The training posttest is a criterion-referenced test for facts, principles and concepts. Questions were revised to avoid compound sentence structure a simple sentences were clearer.

Questions 17-20 were originally in the matching section, but were converted to multiple choice to reduce the length of the matching choice section. The subjects did not like the complexity of the matching section and wanted more white space on the page. This echoed their opinion for more white space on the cards in the computer-based training.

## **Subjects**

**Selection.** The industrial population is the target group for using the research results. Two Bristol, Virginia, manufacturers were contacted and they allowed access to their hourly employees for voluntary participation in this research. See Appendix 8 for company descriptions. After Institutional Review Board approval, a formal request for subjects was posted at these companies. All subjects were scheduled through company representatives.

**Compensation.** The Industrial and Systems Engineering Department provided \$200 to underwrite this research. The customary rate for on-campus research payment is \$5 per hour and this rate was also used at the industrial sites. At the end of each experimental session, the experimenter paid all subjects in cash for their time.

## **Apparatus**

**Software.** The computer-based training was coded in HyperTalk for Apple's HyperCard version 2. A standard background was used to display the information and provide navigational control. See Appendix 9 for screen design.

**Hardware.** A Macintosh Plus with mouse, keyboard, and external 80 megabyte drive presented the computer-based training program. ANSI/HFS 100 guidelines were followed for computer usage.

**Experiment location.** The experiments were conducted on-site at the participating companies and both provided an appropriate private room for the research. It was not feasible to conduct the research at the same off-site location for subjects from both companies.

**Supporting materials.** The following materials supported the research:

1. Pens and pencils,
2. Subject informed consent forms,
3. Cards with assigned “employee number”,
4. Random number table to assign subjects to experimental conditions,
5. Experiment protocol checklist,
6. Payment receipt forms,
7. Sample MSDSs,
8. Subject workbooks, and
9. Meylan # 602 stopwatch.

## **Experimental Protocol**

A pre-experimental checklist of necessary software, hardware, and supporting materials was prepared and used to assess the physical set-up of the experiment.

These procedures were followed for each subject in the experiment:

1. Load software,
2. Greet subject and seat at table,
3. Provide informed consent form. (Appendix 1),
4. Subjects read informed consent text,
5. Obtain informed consent from subjects, else dismiss subject,
6. Subject takes background assessment quiz about MSDS usage habits, preferences, etc. (Appendix 2),
7. Seat subject at computer. Adjust mouse for left- or right-handed use,
8. Observe subject start HyperCard stack and key “employee number”,

9. Subject begins training session at a randomly assigned complexity level,
10. Experimenter explains Borg rating scale for use during posttest,
11. Subject takes training posttest,
12. Experimenter prints data and makes floppy backup,
13. Debrief subject on posttest scores and other subject concerns,
14. Have subject sign payment receipt,
15. Pay subject,
16. Dismiss and thank subject,
17. Store records, and
18. Reset software, etc. for next subject.

## RESULTS

### **Institutional Review Board**

All subjects read and signed the Informed Consent Form at the beginning of the experiment. Most subjects had no questions about the form, but a few did ask why the form was necessary. Additionally, two subjects requested that research summary information be sent directly to them.

### **Course disclaimer and introduction**

A random 5-digit “employee number” tracked subject data on the Disclaimer and Introduction form, computer-based training session, Posttest, MSDS rating, and text passage rating. For data analyses, a subject number ranging from 1 to 24 replaced the “employee number.” This scheme keeps subjects from identifying their own data since the subjects did not know to which training level they were randomly assigned.

Subjects were 18 or older with at least a high school or equivalent degree and currently employed in a manufacturing environment regulated by the Hazard Communication Standard (HCS). Table 2 lists the eight demographic questions and subject responses. A Mood median test found a significant difference ( $p < 0.001$ ) between age and reported frequency of MSDS usage. Older workers said they read MSDSs more often.

**TABLE 2**  
**Demographic Data**

Questions	Answers
1. I have attended a company-sponsored Hazard Communication Training Program.	No 0.0% Yes 100.0%
2. When was your last training session?	1 year ago 33.3% 6 months ago 33.3% 3 months ago 8.3% last month 25.0% this month 4.2% don't know 4.2%
3. I have read the MSDS for _____ the chemicals I work with.	all 20.8% most 33.3% some 25.0% few 12.5% none 8.3%
4. I work with hazardous chemicals on my job.	continously 16.7% most 4.2% sometimes 50.0% rarely 12.5% never 16.7%
5. I have been at my present job for	10 years or more 29.2% 7 years 4.2% 5 years 37.5% 3 years 20.8% 2 years 0.0% 1 year 4.2% less than 1 year 4.2%
6. I am	male 91.7% female 8.3%
7. I am _____ years old.	18-20 0.0% 21-30 25.0% 31-40 25.0% 41-50 41.7% 51-60 8.3% 61-65 0.0% over 65 0.0%
8. I have _____ used a computer with a mouse.	never 29.2% sometimes 29.2% occasionally 37.5% always 4.2%

## Computer-based training

Reading speeds. Scatterplots of the data were made before statistical computations to overview the results and highlight any outlying data points. Figure 3 is a scatterplot of the reading times for the three computer-based training courses. The few outlying data points were accidental double clicks of the mouse and occurred mainly in the introduction cards. The average reading speeds in words/sec for each of the three  $B_1$  levels are 3.1, 3.4, and 3.1 for the Low, Mid, and High versions, respectively. Note that the common cards of the introduction and conclusion were not included in the reading speed calculations. An ANOVA for the average reading speeds ( $\alpha = 0.05$ ) detected no differences ( $p > 0.73$ ) between the three  $B_1$  levels.

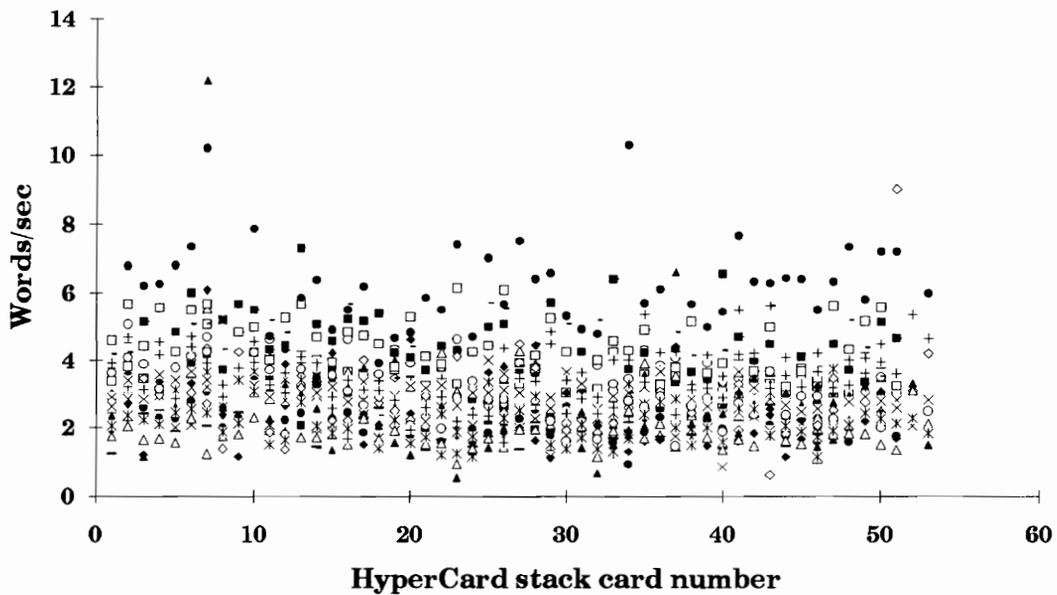


Figure 3. Reading speed scatterplot for all computer-based training versions. A different symbol designates each of the 24 subjects.

## Posttest

**Normality check.** The posttest dependent measures of response accuracy or performance (P), time to answer the question (QT), time to rate the question (RT), and the difficulty rating for each question (D) were obtained from each subject. Following the Minitab Reference Manual (1993, p. 13-9), the correlation of each dependent measure with its normalized scores served as a normality check and they ranged from 0.639 to 0.987. However, none were significant ( $p > 0.05$ ). Subsequently, nonparametric analyses are appropriate and include the Umbrella Alternatives Test (Mack and Wolfe, 1981) for the between subject means and Friedman tests for the within subject data.

**Umbrella alternatives test.** The Umbrella Alternatives Test analyzed the between subject posttest means (Table 3) for P, QT, RT, and D at the  $\alpha = 0.05$  level. For P, the Umbrella Alternatives Test yielded a p-value  $> 0.05$ . No differences were detected between the three training versions on the other posttest dependent measures (QT, RT, and D) either.

TABLE 3  
Posttest dependent measure means

Dependent measure	Training version		
	Low $B_1 = 0.31$	Mid $B_1 = 0.39$	High $B_1 = 0.48$
Performance (P) <i>% correct</i>	61.3	71.8	66.1
Question Time (QT) <i>in minutes</i>	0.52	0.54	0.52
Rating Time (RT) <i>in minutes</i>	0.06	0.07	0.06
Difficulty Rating (D) <i>9-level Borg scale</i>	3.5	3.4	3.4

**Friedman tests.** Gibbons (1976, p. 342) suggests the Friedman test for within subject data as “a realistic alternative procedure to consider in any of the following cases:

1. The sample sizes are quite small.
2. The only data available are measured on an ordinal scale within each block.
3. The respective sample medians seems to be more reliable than sample means for a comparison between treatment effects.
4. The population medians seem to be more representative parameters for the comparison of interest.
5. The assumption of normality and/or equal variances is questionable.
6. Little or nothing can be assumed about the probability distributions.

The data are drawn from a small sample size ( $n = 8$ ) and the normality assumption is questionable. For the posttest within subject data the Friedman tests of P and Question by Subject, QT and Question by Subject, RT and Question by Subject, and D and Question by Subject were all significant ( $p < 0.001$ ). A series of paired comparisons were then made with critical differences equal to  $|R_u - R_v| \geq z_{\alpha/k(k-1)} \sqrt{\frac{Nk(k+1)}{6}}$  (Siegel and Castellan, 1988, p. 180). Appendix 7 provides the paired comparisons with critical differences shaded.

**Regression.** A series of regressions were performed to predict posttest performance (P). The model (regression p-value  $< 0.001$ ) that accounted for the most variance ( $R^2 = 0.581$ ) is  $P = 0.439 + 0.0143QT - 0.0609D$ . This equation indicates that accuracy of performance on the posttest increases with more time spent answering questions and that the more difficult questions reduce posttest performance. Note that the  $B_1$  level was not a significant predictor.

**Relative condition efficiency.** Following Paas and van Merriënboer (1993, pp. 737-743), subjects used a modified 9-level Borg scale for mental effort to rate each posttest question. The posttest performance (P) and difficulty rating (D) scores were combined to yield a measure of relative condition efficiency (E) for the three training conditions. First, the raw P and D scores were converted to z-scores. Second, these z-scores were converted to efficiency ratings using the formula  $E = \frac{|D - P|}{\sqrt{2}}$ . Scores above and to the left of the 0% efficiency line have high efficiency. Scores below and to the right of the 0% efficiency line have low efficiency. Figure 4 presents a scatterplot of all relative condition efficiency scores. The Mid level appeared to be the most efficient, as predicted, but a one-way ANOVA on the relative condition efficiency scores detected no differences between the three training levels ( $p = 0.538$ ).

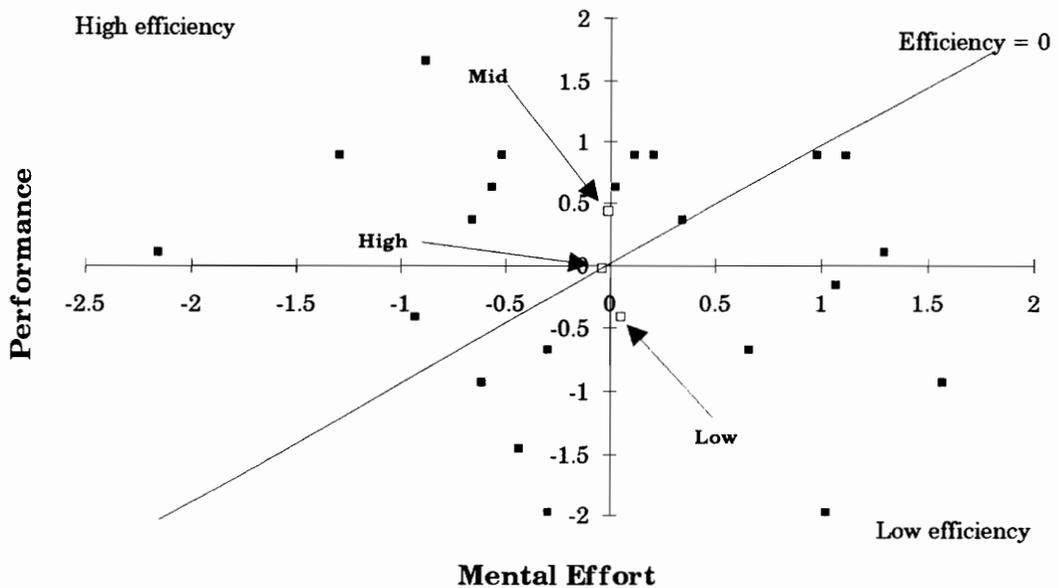


Figure 4. *Relative condition efficiency scores scatterplot.*

## **MSDS rating**

**Reading speed.** Subject reading speed on the distractor MSDS rating task served as a repeated measure to compare with the computer-based training and  $B_1$  level comparison reading speeds. The actual number of words per section divided by the rating time approximates reading speed since the reading time also includes the rating time. However, based on posttest results, rating time accounted for only a small percentage of the total time spent on each question. With this conversion to reading speed, the Friedman results were also significant ( $p < 0.001$ ).

## **$B_1$ level comparisons**

Subjects read three text passages drawn from the three  $B_1$  levels presented in a Latin square to control order effects. ANOVAs checked for and found no order effects for the mean rating time ( $p = 0.861$ ) or difficulty ratings ( $p = 0.891$ ). Subjects did compare the  $B_1$  levels independently of their original training condition. The rating times were standardized to reading speed in words per minute and ANOVAs detected no significant differences between group means ( $p = 0.74$ ). Also, no significant regression models could be obtained from these data.

## **Power analyses**

*A priori* power analysis was based on previously published effect sizes and using one-way ANOVAs for data analysis. However, non-parametric tests were required since the data were not normal and they inherently have lower power for a given sample size compared with a parametric counterpart. The Umbrella Alternatives test was the most appropriate and powerful non-parametric test for the ordered alternative hypotheses.

**Umbrella alternatives test.** Published Umbrella Alternatives Test power analyses (Mack and Wolfe, 1981, p. 180) did not provide power estimates for this experimental design of three groups ( $k = 3$ ) with eight subjects each ( $m = 8$ ). Additional unpublished power estimates were not available from the test developers (Mack, personal communications, March 2, 1994), but Dr. Mack did provide his algorithm for Monte Carlo power estimation. With a  $k = 3$  and  $m = 8$  experimental design, the estimated power is 43%.

**Effect size.** Previous research with the  $B_1$  metric reported very large effect sizes. The overall effect size for this experiment, though, was *one-tenth* the expected size. Power analyses from Kraemer and Thiemann (1987) indicate that the Low and Mid and the Mid and High versions may be different. The Low and High versions probably are not. When these values are converted to sample sizes required for paired t-tests to detect the suspected differences with 80% power, then for Low vs. Mid comparison needs an  $n = 18$ , the Mid vs. High an  $n = 22$ , and the Low vs. High an  $n = 3136$ . This implies that the Mid level is different from both the Low and High levels and that the Low and High levels do not differ from each other. This contradicts published results. All other experiments using the  $B_1$  metric have reported better performance under higher  $B_1$  levels (generally from 0.4 to 0.6).

## DISCUSSION

### Power

The experiment was designed with sufficient power to detect differences based on a very large effect size. Since the observed effect size was very small, the effective power was reduced to approximately 43%. The recurring failure to reject the null hypotheses leads to these possible reasons for negative results:

1. no differences exist, or
2. there was insufficient power to detect differences if they exist.

If no differences exist, then the  $B_1$  metric would be a poor and unreliable performance predictor. Indications of this include a performance plateau, small effect size and instructional design robustness. If there was not enough power, then it is possible that unplanned interactions occurred between the training and testing materials and the subjects.

**Performance plateau.** Previous research typically compared training versions at very low and high average  $B_1$  levels (0.25 and 0.60). Little research dealt with average values in the mid-range. This research may have discovered a performance plateau since average  $B_1$  values between the ones studied did not result in detectable performance differences. The values used may be in a null range which is the “band or set of values that we consider ‘trivial,’ ‘unimportant,’ or ‘negligible,’ [and] which we are willing to assert is functionally equivalent to the complete absence of treatment effects” (Keppel, 1991, p. 89). The exact performance peak is not known, but previous research indicates that higher values ( $> 0.25$ ) are better.

Previous research also indicates large effect sizes. If the  $B_1$  metric really does measure meaningful differences between the training texts, then it would be a good

predictor of performance. However, the average  $B_1$  level may not be such a good predictor since the obtained effect size is small at only one-tenth published results. Even with statistical significance between the different  $B_1$  levels used, the obtained small effect size may render the results with no practical significance in training development and evaluation. “Most researchers are unwilling to commit the resources necessary . . . [since] an experiment that is specifically designed to prove the null hypothesis usually requires a huge commitment of subjects. . . to show that a particular effect does not exist” (Keppel, 1991, p. 90). In this case it is unlikely that resolution will occur since more than 10,000 subjects are required for the high power to “prove” the null hypothesis of no difference.

The statistically non-different results reflect positively on the instructional design methodologies used. Elaboration Theory and Component Display Theory may be robust to changes in  $B_1$  levels within the range of this experiment (0.31 to 0.48). The degree to which trainers use proper instructional design techniques to create training materials may be a better predictor of performance.

**Unplanned interactions.** If the previous effect sizes were reliable, then unknown and unplanned interactions may have occurred and depressed performance score differences. Candidates include reading level,  $B_1$  creation methods, sample size, posttest length, and subject pre-existing knowledge.

One possible interaction that could have equalized performance scores was the reading level (13.7 or 13.8) between the training versions. During formative evaluation, subjects did not indicate that reading level made the text hard to read or understand. However, new training materials should be prepared at a lower grade level such as 8 or 9 and the experiment replicated. This reduction in the reading level does not necessarily mean that the content has to be boring or unappealing to

readers with greater skills. For example, Lincoln's Gettysburg Address only rates a 9 (Gunning, 1952).

The average  $B_1$  creation method previously used of switching sentences is simplistic. The metric may not be an appropriate comprehension predictor when a more skillful method is used that is based on instructional design and systems training principles. This approach sequentially modifies training texts to obtain statistically different average  $B_1$  values.

Another unplanned occurrence was the exhaustion of the corporate subject pool. If a larger sample size had been available then more stable means may have been produced and significance obtained between the three training conditions. In using the Umbrella Alternatives test, only one interchange of a high and low score from the High and Mid level would have resulted in significance. There were, however, no rational bases to eliminate any data.

A longer posttest could have reduced the probability of ties. The ties between seven subject posttest performance (P) means were not expected given the 31 test items. The Umbrella Alternatives test expected a tie probability of zero, but used the Mann-Whitney tie counting method of adding one-half instead of one. This reduces the value of the test statistic and increases the likelihood of null hypothesis rejection failure.

Another possible interaction is that the subjects' pre-existing MSDS knowledge contaminated the posttest measures. To investigate, a series of Mood median tests of posttest dependent measures and demographic data were performed, but only the Mood median test of posttest difficulty (D) and age was significant ( $p = 0.01$ ). Younger subjects rated the posttest as more difficult even though they had been out of school less time and should have been more at ease taking tests. The

younger subjects may have had less experience reading MSDSs and/or less *a priori* knowledge of the chemical safety information presented and tested in the training program.

### **Future research**

The previous discussion of the results offers many future research opportunities. These include manipulation of the  $B_1$  metric as an independent variable and analysis tool as follows.

**No pre-existing knowledge.** A suggested replication study is a training topic of which the target training population has no *a priori* knowledge. Subjects could be trained to use isopleths (lines of equal value) in chemical safety. For example, teach them with different average  $B_1$  levels how to determine personal protective equipment (PPE) requirements using isopleths of airborne chemical ppm levels and compare between group performance.

**Learner control.** Future training programs could branch younger workers to more practice items and reduce the perceived difficulty of chemical hazard concepts. This branching would be under learner control which must be operationally defined within the training context. Once defined, do  $B_1$  levels affect the perception or desire for different amounts of learner control? To date, no research has been conducted in this area with the  $B_1$  metric.

**Media.** Previous research presented audio-taped lessons to which subjects listened. In this experiment, subjects only read computer-generated text. It is possible that aural presentation differs from reading with respect to  $B_1$  level sensitivity. A suggested experiment is to equate presentation rates using identical material and compare between group performance to different media.

**Domain of learning.** The predictive power of  $B_1$  levels may vary across Gagné and Briggs' (1979) domains of learning. These five areas are intellectual skills, cognitive strategies, verbal information, attitudes, and motor skills. Targeted research in each domain could determine the  $B_1$  effect size in each. Research into a possible optimal value or range of  $B_1$  to change trainee attitudes would be very useful in safety training.

**Long-term retention.** If the trainees do differentially refresh their memories concerning chemical safety during training, how long will it last? This is very important since all workers covered under HCS are, by definition, foreseeably exposed to chemical hazards. Different average  $B_1$  levels may cause different retention rates which follow-up studies may reveal.

**Emergency response.** Future research could investigate the impact of  $B_1$  levels on speed and accuracy of simulated emergency responses to a chemical emergency (i.e., spill, leak, explosion, body contamination). How quickly and accurately can the workers find the appropriate information in the MSDS? Mean  $B_1$  levels may also be indicators of strategy shifts. The effect of sudden changes in mean  $B_1$  levels between tasks could be studied with the Law of Transformations (Venda and Venda, 1991) which states that a performance decrement always occurs during strategy shifts.

**Hypertext a posteriori  $B_1$  calculation.** An alternative approach is inductive reasoning. One could deconstruct the effective mean  $B_1$  levels from the paths subjects take in a hypertext environment. For example, given a standard search task, do the self-selected  $B_1$  levels map to performance measures? If so, then they could be used to predict successful learner paths in a hypertext environment. An on-line heuristic could warn if the path is too erratic for effective learning.

**Sequential experimentation.** If a certain range of the  $B_1$  metric alone can be shown statistically to produce different performance, then the  $B_1$  metric has utility in sequential experimentation in relating and/or comparing different training experiments. Further study may be made if the training texts of other experiments were analyzed and converted to  $B_1$  values and subject performance mapped to the different  $B_1$  levels.

### **Conclusion**

Fundamentally, the issue is relevancy. The  $B_1$  metric quantifies text and is easy to use with word processing macros and a spreadsheet, but what is its pedagogical value? Should it be a recommended instructional design and training evaluation tool? On the basis of this research, the  $B_1$  metric cannot be recommended as a *stand-alone* evaluation or prediction tool. It may, however, be useful when viewed in a systems context. The  $B_1$  metric shares a common theme with the many traditional metrics (i.e., Gunning Fog Index, word count, etc.). It quantifies a text, but it can oversimplify analyses if used in isolation. Research with the  $B_1$  metric should continue given the dearth of instructional design and training system quantitative guidelines.

This research followed the systems approach to training and used appropriate research design to control validity threats. Both formative and summative evaluations determined in a statistically and educationally defensible fashion if the training program fulfilled its training objectives for the target training population. This iterative evaluation process benefits the users, developers, and evaluators since it delivers a more refined, focused, and educationally relevant training program. Such a process is necessary given the current understanding of human information processing and instructional design theory (Merrill, Jones, and Li, 1990a, 1990b,

1990c; Li, Jones, Merrill, and Aurich, 1992). It is not currently possible to prescribe the amount and type of transactions required for learner acquisition of system behavior as a whole. However, many tools are available to systematize training development. It is in this area that the  $B_1$  metric may serve as a predictive, analytical tool. Corporate trainers would welcome any tool that reduces training development costs and maximizes learning especially if that training is a government mandate.

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## Appendix 1 Subject Informed Consent Form

## **PARTICIPANT'S INFORMED CONSENT FORM**

In the experiment, you will be asked to complete a computer-based training program regarding chemical safety. At the end of the training, you will be asked to take a computer-based test. No previous computer experience is required. The one session experiment is expected to take 90 minutes.

Please note that *only the training system is under study*. **You are not.**

You have certain rights as a volunteer subject. This form will list those rights and obtain your written consent to voluntarily to participate in the study. Your rights as a subject are:

1. You have the right to withdraw from this study at any time and for any reason by simply informing the experimenter.
2. You have the right to inspect your data and withdraw them from the experiment if you feel that you should for any reason. Data are processed and analyzed after a subject has completed the study. At that time, these data will be treated with anonymity since all identifying information will be removed from the data. No one else will have access to your data.
3. You have the right to be informed of the overall results of this study. If you wish to receive an overview of the results, include your address with your signature below.

4. If you have any questions prior to data collection please feel free to ask. The experimenter will provide answers to your questions unless the outcome of the study will be influenced. Answers which may influence the study will be delayed until after data collection, at which time full and complete answers will be given.
5. There is minimal risk to you as a participant in this study. You will be using experimenter provided computer- and paper-based training and testing materials.
6. You will be paid at the rate of \$5 per hour for your time.

If you have further comments or questions about your rights as a participant, please contact Ernie Stout, the chairman of the Institutional Review Board for the Use of Human Subjects in Research at:

Research Division  
306 Burruss Hall  
Virginia Polytechnic Institute and State University  
Blacksburg, VA 24061  
(703) 231-6077

The experimenter for the study will be Albert Moore, a graduate student in Industrial and Systems Engineering. He may be contacted at:

Industrial and Systems Engineering  
271 Whittemore Hall  
Virginia Polytechnic Institute and State University  
Blacksburg, VA 24061-0118  
(703) 231-5586

The faculty advisor for the study will be Dr. Robert C. Williges, a professor of Human Factors in Industrial and Systems Engineering. He may be contacted at:

519 G Whittemore Hall (0118)

Virginia Polytechnic Institute and State University

Blacksburg, VA 24061

(703) 231-6270

Your signature below indicates that you have read this document in its entirety, and understand your rights as a participant as listed above, and that you consent to participate. Thank you for your cooperation.

*I have read a description of this study and understand the nature of the research and my rights as a participant. I hereby consent to participate, with the understanding that I may discontinue participation at any time if I so choose.*

\_\_\_\_\_  
Participant's Signature

\_\_\_\_\_  
Date

\_\_\_\_\_  
Printed Name

## Appendix 2 Demographic Survey

## **COURSE INTRODUCTION & DISCLAIMER**

Although some of the information may be new to you, this training program will try to make it as easy as possible for you to learn the information. The hazard communication standard requires that companies provide you with training. You probably have already attended a hazard communication training session at your company in the past.

This experiment is not intended to substitute for company-sponsored training. This experiment is simply a research effort to learn more about how the hazard content can be presented more effectively.

In allowing Virginia Tech to perform this research at your company, Sandvik Rock Tools, Inc. demonstrates its commitment to workplace safety and supporting the intent of the Occupational Health and Safety Administration's (OSHA) Hazard Communication Standard to "reduce the incidence or chemical source illness and injury" in the workplace.

Note, again, that this information does not replace any company policy or procedure. Please discuss with your supervisor before trying to use any information you learn in this training experiment.

Before we begin the computer-based training, however, it would be helpful to answer the following questions. Remember, no one other than the experimenter will see your responses. Also, there are no "right" or "wrong" answers. Just answer truthfully.

The following questions are to develop summary data about participants. The data will be presented only in summarized formats (averages, frequency counts, etc.).

Information regarding individual responses will not be available to your company.

Please write in your "employee number" below

# \_\_\_\_\_.

This "employee number" is used for experimental purposes ONLY. It is not part of your company records.

Please answer the following EIGHT questions.

\_\_\_\_\_ 1. I have attended a company-sponsored Hazard Communication Training Program.

- a. NO
- b. YES

If no, please stop and tell the experimenter.

If yes, then continue to question 2

\_\_\_\_\_ 2. Approximately when was your last training session:

- a. 1 year ago
- b. 6 months ago
- c. 3 months ago
- d. last month
- e. this month
- f. don't know

\_\_\_\_\_ 3. I have read the Material Safety Data Sheets (MSDS) for \_\_\_\_\_ the chemicals I work with.

- a. all
- b. most
- c. some
- d. few
- e. none

\_\_\_\_\_ 4. I work with hazardous chemicals on my job \_\_\_\_\_.

- a. continuously during a shift
- b. most of the shift
- c. sometimes on the shift
- d. rarely on the shift
- e. never on the shift

- \_\_\_\_\_ 5. I have been at my present job for
- a. 10 years or more
  - b. 7 years
  - c. 5 years
  - d. 3 years
  - e. 2 years
  - f. 1 year
  - g. less than 1 year
- \_\_\_\_\_ 6. I am a
- a. male
  - b. female
- \_\_\_\_\_ 7. I am \_\_\_\_\_ years old.
- a. 18-20
  - b. 21-30
  - c. 31-40
  - d. 41-50
  - e. 51-60
  - f. 61-65
  - g. over 65
- \_\_\_\_\_ 8. I have \_\_\_\_\_ used a computer with a mouse.
- a. never
  - b. sometimes
  - c. occasionally
  - d. always

## Appendix 3 Mental Effort Rating Practice

For each question you will be asked to rate the amount of mental effort or simply how hard you feel that you must work to answer the question.

To indicate the level or amount of mental effort circle the term on the scale that most closely matches your feelings. The scale has nine different levels. The lowest level is very, very easy. The highest scale value is very, very difficult.

An example of using the scale follows:

Please indicate the amount mental effort needed to understand the following paragraph.

“Oxygen deficiency designates an atmosphere having less than the percentage of oxygen found in normal air. Normally, air contains approximately 21 percent oxygen at sea level. When the oxygen concentration in air is reduced to approximately 16 percent, many individuals become dizzy, experience a buzzing in the ears, and have a rapid heart beat. Respirators capable of supplying adequate oxygen must be worn when oxygen concentrations fall below 19.5 percent in air.”

The amount of mental effort to understand this paragraph is \_\_\_\_\_.

Circle ONE response.

very,very  
easy

very easy

somewhat  
easy

easy

neither easy  
nor difficult

somewhat  
difficult

difficult

very difficult

very, very  
difficult

If you have any questions about using this scale, please ask the experimenter now.

## Appendix 4 Course Outline

## Course Outline

- I. Background/Introduction
  - A. Risk
    - 1. People/Health (emphasized)
    - 2. Property
    - 3. Environment
  - B. Risk/Benefit analogy
  - C. Risk in the workplace
  - D. Role of HCS training
  - E. Role of MSDS & Goal of this course
  
- II. Exposure/Routes of Entry
  - A. Inhalation (emphasized)
  - B. Injection
  - C. Skin absorption
  - D. Ingestion
  
- III. Section II of MSDS: Hazardous Ingredients/Identity Information
  - A. Chemical identification
  - B. Hazardous components
    - 1. Mixture
    - 2. Concentration
    - 3. Measurements of concentration
      - a. OSHA PEL
      - b. PEL-TWA
      - c. PEL-STEL
      - d. PEL-C
  
- IV. Section III of MSDS: Physical/Chemical Characteristics
  - A. Evaporation rate
  - B. Vapor density

- V. Section VI of MSDS: Health Hazard Data
  - A. Routes of entry (review)
  - B. Type of hazard
    - 1. Acute
    - 2. Chronic
  - C. Carcinogenicity
  - D. Signs and symptoms of exposure
  - E. Medical conditions
  - F. Emergency and first aid procedures
- VI. Section VIII of MSDS: Control Measures
  - A. Ventilation (engineering control)
  - B. Personal Protective Equipment (PPE)
    - 1. Respiratory
    - 2. Gloves
    - 3. Eye protection
  - C. Work and hygienic practices
- VII. Conclusion

## Appendix 5 Posttest

Subject # \_\_\_\_\_

Multiple choice: Choose the best answer. Write your answer in the blank to left of the question number.

There is only one correct answer for each question.

- \_\_\_\_\_ 1. The MSDS will help you most in assessing risk to which of the following:
- a. people
  - b. property
  - c. environment
  - d. all of the above

The amount of mental effort to answer this question is \_\_\_\_\_.

very,very easy    very easy    somewhat easy    easy    neither easy nor difficult    somewhat difficult    difficult    very difficult    very, very difficult

- \_\_\_\_\_ 2. The less of a chemical that is dissolved in a mixture the \_\_\_\_\_ the risks associated with that chemical.
- a. more
  - b. fewer
  - c. same

The amount of mental effort to answer this question is \_\_\_\_\_.

very,very easy    very easy    somewhat easy    easy    neither easy nor difficult    somewhat difficult    difficult    very difficult    very, very difficult

- \_\_\_\_\_ 3. Suppose you work with isopropanol. Your new supervisor, however, refers to this chemical as isohol. You can be sure that both of you are talking about the same chemical if you:
- a. contact the chemical manufacturer
  - b. look up the chemical in the dictionary
  - c. check the CAS #

The amount of mental effort to answer this question is \_\_\_\_\_.

very,very easy    very easy    somewhat easy    easy    neither easy nor difficult    somewhat difficult    difficult    very difficult    very, very difficult

- \_\_\_\_\_ 4. The three physical states of matter are:
- a. gas, solid, air
  - b. solid, liquid, gas
  - c. fluid, water, solid
  - d. none of the above

The amount of mental effort to answer this question is \_\_\_\_\_.

very,very easy    very easy    somewhat easy    easy    neither easy nor difficult    somewhat difficult    difficult    very difficult    very, very difficult

\_\_\_\_\_ 5. The state of matter that has the fastest dissolving rate is:

- a. liquid
- b. gas

The amount of mental effort to answer this question is \_\_\_\_\_.

very, very easy    very easy    somewhat easy    easy    neither easy nor difficult    somewhat difficult    difficult    very difficult    very, very difficult

\_\_\_\_\_ 6. Which of the following are measurements of the amount of each component in a mixture?

- a. chemical concentration
- b. percents
- c. parts per million (ppm)
- d. all of the above

The amount of mental effort to answer this question is \_\_\_\_\_.

very, very easy    very easy    somewhat easy    easy    neither easy nor difficult    somewhat difficult    difficult    very difficult    very, very difficult

\_\_\_\_\_ 7. The PEL, PEL-STEL and PEL-C are

- a. names of chemicals
- b. chemical manufacturers
- c. measurements of exposure limits
- d. are usually listed in ppm (parts per million)
- e. c and d
- f. none of the above

The amount of mental effort to answer this question is \_\_\_\_\_.

very, very easy    very easy    somewhat easy    easy    neither easy nor difficult    somewhat difficult    difficult    very difficult    very, very difficult

\_\_\_\_\_ 8. All of the following are routes of exposure except:

- a. ingesting
- b. exhalation
- c. inhalation
- d. skin absorption
- e. injection

The amount of mental effort to answer this question is \_\_\_\_\_.

very, very easy    very easy    somewhat easy    easy    neither easy nor difficult    somewhat difficult    difficult    very difficult    very, very difficult

\_\_\_\_\_ 9. The most common exposure route and the most difficult one to control is:

- a. injection
- b. inhalation
- c. skin absorption
- d. ingestion
- e. exhalation

The amount of mental effort to answer this question is \_\_\_\_\_.

very, very easy    very easy    somewhat easy    easy    neither easy nor difficult    somewhat difficult    difficult    very difficult    very, very difficult

\_\_\_\_\_ 10. The speed at which a liquid turns into a vapor is the:

- a. boiling point
- b. specific gravity
- c. vapor density
- d. evaporation rate

The amount of mental effort to answer this question is \_\_\_\_\_.

very, very easy    very easy    somewhat easy    easy    neither easy nor difficult    somewhat difficult    difficult    very difficult    very, very difficult

\_\_\_\_\_ 11. The vapor density of air is one. If the vapor density of chemical A is greater than one, then it will (1)\_\_\_\_\_ in air. If the vapor density of chemical B is less than one, then it will (2)\_\_\_\_\_ in air.

- a. (1) fall (2) rise
- b. (1) rise (2) fall
- c. (1) fall (2) fall
- d. (1) rise (2) rise

The amount of mental effort to answer this question is \_\_\_\_\_.

very,very easy    very easy    somewhat easy    easy    neither easy nor difficult    somewhat difficult    difficult    very difficult    very, very difficult

\_\_\_\_\_ 12. The standard evaporation rate for carbon tetrachloride is 1. Chemical A has an evaporation rate of 2.2. Chemical B has an evaporation rate of 0.6. Under identical conditions, which chemical will evaporate faster?

- a. Chemical B
- b. Chemical A
- c. Chemical A and Chemical B will evaporate at the same rate

The amount of mental effort to answer this question is \_\_\_\_\_.

very,very easy    very easy    somewhat easy    easy    neither easy nor difficult    somewhat difficult    difficult    very difficult    very, very difficult

\_\_\_\_\_ 13. Which of the following would not be an example of an acute risk:

- a. inhaling vapors from a sudden spill
- b. developing cancer
- c. getting splashed with a chemical
- d. being accidentally stabbed with a sharp object

The amount of mental effort to answer this question is \_\_\_\_\_.

very, very easy    very easy    somewhat easy    easy    neither easy nor difficult    somewhat difficult    difficult    very difficult    very, very difficult

\_\_\_\_\_ 14. One day, while moving a heavy box, you accidentally knock over an open barrel of chemical Z. All of a sudden you feel dizzy and nauseous. This type of exposure would most likely be described as:

- a. chronic
- b. acute

The amount of mental effort to answer this question is \_\_\_\_\_.

very, very easy    very easy    somewhat easy    easy    neither easy nor difficult    somewhat difficult    difficult    very difficult    very, very difficult

- \_\_\_\_\_ 15. Suppose you were splashed with a chemical that started to burn through your clothing. What would you do?
- a. consult the MSDS and seek treatment for the burn
  - b. be glad that you will have set the latest fashion trend
  - c. put on some protective clothing and go back to work
  - d. none of the above

The amount of mental effort to answer this question is \_\_\_\_\_.

very,very easy    very easy    somewhat easy    easy    neither easy nor difficult    somewhat difficult    difficult    very difficult    very, very difficult

- \_\_\_\_\_ 16. All of the following are examples of Personal Protective Equipment (PPE) to help prevent chemical exposure except:
- a. ventilation
  - b. splash shields and chemical safety glasses
  - c. respirator
  - d. protective gloves
  - e. aprons and boots

The amount of mental effort to answer this question is \_\_\_\_\_.

very,very easy    very easy    somewhat easy    easy    neither easy nor difficult    somewhat difficult    difficult    very difficult    very, very difficult

\_\_\_\_\_ 17. Where would you find a chemical's evaporation rate on the MSDS?

- a. Section II: Hazardous Ingredients/Identity Information
- b. Section III: Physical/Chemical Characteristics
- c. Section VI: Health Hazard Data
- d. Section VIII: Control Measures

The amount of mental effort to answer this question is \_\_\_\_\_.

very, very easy    very easy    somewhat easy    easy    neither easy nor difficult    somewhat difficult    difficult    very difficult    very, very difficult

\_\_\_\_\_ 18. Where would you find a chemical's ceiling permissible exposure limit (PEL-C) on the MSDS?

- a. Section II: Hazardous Ingredients/Identity Information
- b. Section III: Physical/Chemical Characteristics
- c. Section VI: Health Hazard Data
- d. Section VIII: Control Measures

The amount of mental effort to answer this question is \_\_\_\_\_.

very, very easy    very easy    somewhat easy    easy    neither easy nor difficult    somewhat difficult    difficult    very difficult    very, very difficult

\_\_\_\_\_ 19. On the MSDS, where would you find information on what type of respirator to use when handling a particular chemical?

- a. Section II: Hazardous Ingredients/Identity Information
- b. Section III: Physical/Chemical Characteristics
- c. Section VI: Health Hazard Data
- d. Section VIII: Control Measures

The amount of mental effort to answer this question is \_\_\_\_\_.

very,very easy    very easy    somewhat easy    easy    neither easy nor difficult    somewhat difficult    difficult    very difficult    very, very difficult

\_\_\_\_\_ 20. If you were overexposed to a chemical and inhaled too much of it, where would you find a listing of signs and symptoms that you would have?

- a. Section II: Hazardous Ingredients/Identity Information
- b. Section III: Physical/Chemical Characteristics
- c. Section VI: Health Hazard Data
- d. Section VIII: Control Measures

The amount of mental effort to answer this question is \_\_\_\_\_.

very,very easy    very easy    somewhat easy    easy    neither easy nor difficult    somewhat difficult    difficult    very difficult    very, very difficult

21. Matching: Match the items in Column A with the items in Column B. Use each item only once.

<u>Column A</u>	<u>Column B</u>
_____ Provides risk information about chemicals	A. people, property, and environment
_____ Categories of risk	B. CAS #
_____ Contact with a hazardous chemical while on the job	C. acute health hazard
_____ Service that provides unique chemical identification	D. PEL-STEL
_____ The result of one material moving inside & dispersing into another	E. ventilation
_____ Amount of chemical concentration over a specified amount of time	F. MSDS
_____ A measurement of dose	G. concentration
_____ Immediate health effect	H. respirator
_____ An example of an engineering control	I. dose rate
_____ An example of PPE	J. exposure
_____ The amount of chemical that is dissolved into a mixture	K. mixture

The amount of mental effort to answer this question is \_\_\_\_\_.

very, very easy      very easy      somewhat easy      easy      neither easy nor difficult      somewhat difficult      difficult      very difficult      very, very difficult

## Appendix 6 Data collection forms



Time per posttest question

Subject #: \_\_\_\_\_

Date: \_\_\_\_\_/94

Co. \_\_\_\_\_

Question #	RawTime		Calc Time			
Multiple Choice	QT	RT	QT	RT	D	P
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						

# Time per MSDS rating question

Subject #: \_\_\_\_\_

Date: \_\_\_\_\_/94

Co. \_\_\_\_\_

Start time: \_\_\_\_\_

Question #	RawTime	Calc Time	Borg
Section	RT	RT	Difficulty
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
B value rating (A,B,C)	RT	CalcTime	Difficulty
1			
2			
3			

**COPY OF RECEIPT FORM**

**ONLY FOR INDUSTRIAL & SYSTEMS ENGINEERING  
DEPARTMENT AT VIRGINIA TECH**

I participated in this experiment \_\_\_\_\_ hours on \_\_\_\_\_, 1994.

The experimenter paid me in cash \$ \_\_\_\_\_ for my time at the rate of \$5 per hour.

Printed Name: \_\_\_\_\_

Signature: \_\_\_\_\_

Social Security Number: \_\_\_\_\_ - \_\_\_\_\_ - \_\_\_\_\_

## Appendix 7 Posttest Data

## Posttest means

Question	P	QT (min)	RT (min)	D
1	0.250	0.293	0.148	1.96
2	0.792	0.366	0.079	3.46
3	0.958	0.398	0.067	3.13
4	0.958	0.275	0.076	2.88
5	0.917	0.238	0.047	2.96
6	0.417	0.292	0.057	3.25
7	0.333	0.407	0.060	4.08
8	0.917	0.214	0.050	2.29
9	0.958	0.203	0.041	2.00
10	0.667	0.244	0.037	3.38
11	0.792	0.743	0.092	3.71
12	0.708	0.457	0.070	4.17
13	0.583	0.467	0.061	3.75
14	0.833	0.336	0.047	3.13
15	0.708	0.411	0.042	2.71
16	0.958	0.450	0.045	3.50
17	0.708	0.360	0.047	3.58
18	0.125	0.346	0.041	3.92
19	0.542	0.349	0.038	3.63
20	0.875	0.413	0.037	3.79
21	0.598	3.72	0.107	6.46

Friedman test of P by Question blocked by Subject

$S = 210.79, df = 20, p < 0.001$  (adjusted for ties)

Significant paired comparison results (at 0.05 level) shaded

Question	21	3	4	9	16	5	8	20	14	2	11	12	15	17	10	13	19	6	7	1	18
Sum of Ranks	498	315	315	315	315	305	305	293	285	274	274	255	255	254	244	225	214	185	164	144	114
	184	184	184	184	194	194	206	214	224	224	244	244	244	254	274	284	314	334	354	384	
		0	0	0	10	10	22	30	41	41	60	60	61	71	90	101	130	151	171	201	
			0	0	10	10	22	30	41	41	60	60	61	71	90	101	130	151	171	201	
				0	10	10	22	30	41	41	60	60	61	71	90	101	130	151	171	201	
					10	10	22	30	41	41	60	60	61	71	90	101	130	151	171	201	
						0	12	20	31	31	50	50	51	61	80	91	120	141	161	191	
							12	20	31	31	50	50	51	61	80	91	120	141	161	191	
								8	19	19	38	38	39	49	68	79	108	129	149	179	
									11	11	30	30	31	41	60	71	100	121	141	171	
										0	20	20	20	30	50	60	90	110	130	160	
											20	20	20	30	50	60	90	110	130	160	
												0	1	11	30	41	70	91	111	141	
													1	11	30	41	70	91	111	141	
														10	30	40	70	90	110	140	
															20	30	60	80	100	130	
																11	40	61	81	111	
																	30	50	70	100	
																		21	41	71	
																			20	50	
																				30	

Friedman test of QT by Question blocked by Subject

$S = 217.22$ ,  $df = 20$ ,  $p < 0.001$  (adjusted for ties)

Significant paired comparison results (at 0.05 level) shaded

Question	21	11	13	12	16	15	3	7	17	19	20	2	18	14	1	4	6	10	5	8	9
Sum of ranks	500	428	349	346	330	314	307	299	282	280	276	271	246	224	219	188	184	150	143	109	106
	73	151	155	171	187	193	202	218	220	225	229	254	277	282	313	317	351	357	392	395	
		79	82	98	114	121	129	146	148	152	157	182	204	209	240	244	278	285	319	322	
			3	19	35	42	50	67	69	73	78	103	125	130	161	165	199	206	240	243	
				16	32	39	47	64	66	70	75	100	122	127	158	162	196	203	237	240	
					16	23	31	48	50	54	59	84	106	111	142	146	180	187	221	224	
						7	15	32	34	38	43	68	90	95	126	130	164	171	205	208	
							9	25	27	32	36	61	84	89	120	124	158	164	199	202	
								17	19	23	28	53	75	80	111	115	149	156	190	193	
									2	7	11	36	59	64	95	99	133	139	174	177	
										5	9	34	57	62	93	97	131	137	172	175	
											5	30	52	57	88	92	126	133	167	170	
												25	48	53	84	88	122	128	163	166	
													23	28	59	63	97	103	138	141	
															5	36	40	74	81	115	118
																31	35	69	76	110	113
																	4	38	45	79	82
																		34	41	75	78
																			7	41	44
																				35	38
																					3

Friedman test of RT by Question blocked by Subject

$S = 98.39, df = 20, p < 0.001$  (adjusted for ties)

Significant paired comparison results (at 0.05 level) shaded

Question	1	2	11	21	3	12	7	13	6	8	4	14	5	15	9	17	18	16	20	10	19
Sum of ranks	444	355	345	333	313	296	294	286	250	246	245	245	242	228	218	213	206	197	194	193	192
	89	99	111	131	148	150	158	194	198	199	199	202	216	226	231	238	247	250	251	252	
		10	22	42	59	62	69	105	109	111	111	113	128	138	142	150	158	161	162	163	
			12	32	49	52	59	95	99	101	101	103	118	128	132	140	148	151	152	153	
				20	37	40	47	83	87	89	89	91	106	116	120	128	136	139	140	141	
					17	20	27	63	67	69	69	71	86	96	100	108	116	119	120	121	
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									4	6	6	8	23	33	37	45	53	56	57	58	
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															5	12	21	24	25	26	
																8	16	19	20	21	
																	9	12	13	14	
																		3	4	5	
																			1	2	
																				1	

Friedman test of D by Question blocked by Subject

$S = 171.41, df = 20, p < 0.001$  (adjusted for ties)

Significant paired comparisons results (at 0.05 level) shaded

Question	21	18	7	12	11	20	17	13	19	16	2	10	14	6	3	5	15	4	8	9	1
Sum of ranks	486	328	327	325	319	308	307	300	296	289	267	247	245	244	238	224	215	181	154	120	119
	158	159	161	167	178	179	186	190	197	219	239	241	242	248	262	271	305	332	366	367	
		1	3	9	20	21	28	32	39	61	81	83	84	90	104	113	147	174	208	209	
			2	8	19	20	27	31	38	60	80	82	83	89	103	112	146	173	207	208	
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																	9	43	70	104	105
																		34	61	95	96
																			28	62	62
																				34	35
																					1

## Appendix 8 Company Descriptions

## Sandvik Rock Tools, Inc.

Sandvik Rock Tools, Inc. is a Swedish-owned company located in the Bristol-Washington County Industrial Park, Bristol, Virginia. The Chemical Products Division manufactures chemical products for strata and ventilation control in underground mining. The Mining Tools Division manufactures carbide-tip cutting tools for the mining and construction industries. Sandvik Rock Tools employs approximately 200 people.

## CAMAC Corporation

CAMAC Corporation is part of the British-owned Cookson Company and is also located in the Bristol-Washington County Industrial Park. CAMAC is the leading non-chemical solution dyed yarn manufacturer in the world in supplying a broad range of yarn types and colors in sample and production size lots. CAMAC employs approximately 400 people.

## Appendix 9 HyperCard Screen Design Sample

But modern industry relies on chemicals, so in order for your company to stay in business, some risk must be tolerated. The key is to know what these risks are and the steps to eliminate and reduce the risks. As an employee, you should be concerned about the risks to your health and what your company is doing to lessen these risks and keep you informed.

CONTINUE

QUIT

## Appendix 10 Word Macro

## Macro to make each sentence a separate paragraph

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## Macro to replace keywords with number

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## Appendix 11 Training Course Text

## TRAINING COURSE TEXT

All activity involves risk. There are three general categories of risk: to people, property, and the environment. The Material Safety Data Sheet (MSDS) addresses all three categories, but much of the risk information is devoted to people. Today, you will learn more about the risk to people.

You may not have thought of your activities in terms of risks and benefits before. You exposed yourself to the risk of an automobile accident by driving to work today. By driving, you were able to get to work so that you may earn money. This is the benefit (money) which you value more than the risk of a car accident. However, in an accident you could have been hurt and your property (your car) could have been damaged. Also, the environment may have been polluted from burning gasoline in the engine. In all cases, however, you perceived the benefits of driving greater than the risks.

Once you are on the job the risk and benefit tradeoffs continue. For example, take the chemicals used in your workplace. They are used even though they may present risks to health, property, and the environment. At work, you can probably think of some products and processes that involve risks of chemical illness and injury. If the chemicals that pose these risks were eliminated, you could not perform your job.

But modern industry relies on chemicals, so in order for your company to stay in business, some risk must be tolerated. The key is to know what these risks are and the steps to eliminate and reduce the risks. As an employee, you should be concerned about the risks to your health and what your company is doing to lessen these risks and keep you informed.

The Hazard Communication Training which you indicated that you already have attended is a good place to start assessing some of the risks of chemical usage. This training is one way that the government, the chemical manufacturers, and your company work together to help reduce the exposure risk of using chemicals. In your Hazard Communication Training you learned about your company's written plan, some of the chemicals in your workplace, labeling and MSDSs.

Material Safety Data Sheets provide a lot of information about the risks associated with chemicals, and they should be available for all hazardous chemicals in your workplace. No doubt, you've seen MSDSs before. However, many people do not feel confident in reading them. The information may not be clear or obvious to you or it may not be in the form you would like. This training will discuss how you can put together a picture of the risks of exposure to chemicals in the air using the MSDS.

Exposure means that you are subjected to a hazardous chemical while on the job and includes the potential or risk of exposure. You can be exposed to chemicals in four ways. A chemical can enter your body by inhalation (or breathing chemical vapors or fumes), absorption through the skin, ingestion, or injection.

Inhalation is the most common exposure route and the most difficult to control. Most common chemicals are either liquids or gases at temperatures normally encountered in industry. When the chemicals evaporate and mix with air they create airborne exposure risks. An airborne chemical will enter your body by inhalation; you breathe it along with the air in your workplace. Especially with inhalation, the risks of exposure to a chemical always exist while it is present in the workplace, but there are ways to reduce the risks. This training program will help

you understand where and how the MSDS provides you with information regarding the health risks from airborne chemical exposure.

First, you need to know what chemicals you are working with and the ways those chemicals may enter your body, particularly inhalation. Section II of the MSDS provides this information. This section, Hazardous Ingredients/Identity Information, contains information on the chemical hazards. It lists the hazardous components of a mixture in order of their concentration and exposure limits for each component.

Sometimes manufacturers add other information in the identity section, including synonyms, trade names, or identifying descriptions such as the chemical formula or Chemical Abstract Service (CAS) number. The CAS number is another way of identifying chemicals. Each CAS number is unique, it is a good way to refer to chemicals since it may reduce confusion. Many chemicals have long and difficult names. Some of them even sound or look similar. Although the names of the chemicals may be difficult, it is wise to learn how to spell and pronounce them correctly. Also, you may agree to use a common name to identify a chemical. A common name may be a trade or brand name; it is any name other than its chemical name.

In order for you to better understand the significance of a chemical concentration, let's review some chemistry. Concentration refers to how much of a chemical is dissolved into a mixture. Whether or not a chemical dissolves depends on its physical state. There are three states of matter, solid, liquid or gas.

When a material, such as a gas dissolves, it undergoes another type of physical change; one material physically moves inside and disperses into another. The result is a mixture. It is important to remember that a chemical's composition and

properties may stay the same even when it is dissolved in something else. Sometimes, however, when chemicals mix, new chemicals may be formed that present additional health hazards. The more of a chemical that is dissolved in a given amount of material, such as water, the greater the risks associated with that mixture. Also, different chemicals dissolve at different speeds. Dissolving occurs fastest for gases, which can make airborne exposure a serious health threat.

In general, when dealing with hazardous materials, the concentration will indicate the relative hazard associated with the mixture. A higher concentration of an airborne chemical mixed in the air tends to be more hazardous than a lower concentration. A concentration is a measurement of the amount of each component in a mixture. Concentrations are expressed in percents, parts per million (ppm), parts per billion, or milligrams per cubic meter. Exposure limits are often listed in parts per million (ppm), which is a measure of the quantity of one substance in another. A part per million is small, but some hazardous chemicals in small amounts can cause a great deal of harm.

The MSDS lists important measurements of the total amount of chemical concentration and the amount of chemical concentration over a specified amount of time. This is what is meant by dose and dose rate. When you take medicine, for example, your doctor may instruct you to take a certain number of pills every few hours. He has prescribed your dose rate of medicine. The actual dose is the total number of pills prescribed.

You can think about a chemical dose in the same way. The dose is the amount of chemical that is taken in to your body. The dose rate is the amount of chemical taken in over some specified amount of time, such as an hour. There are

several measurements on the MSDS that indicate the legal dose for airborne chemical exposure.

The OSHA PEL, or the Permissible Exposure Limit, is the maximum airborne concentration allowed for exposure. This concentration is often listed as a PEL-TWA, which is an employee's average airborne exposure that cannot be exceeded in any eight-hour work shift of a 40-hour work week.

The PEL-STEL, or short-term exposure limit, is an employee's 15-minute time-weighted average exposure that cannot be exceeded at any time during a work day. For some substances, other times may be specified. The PEL-C, or ceiling limit, is an employee's exposure that cannot be exceeded.

Once you know about the names and measurements of hazardous ingredients, you need to understand their physical and chemical characteristics. Then with proper training, you'll be able to work with these chemicals. The MSDS tells you in Section III how readily a chemical evaporates. It also tells you more about what happens to the chemical once it does evaporate and mixes with air.

Evaporation rate is the speed at which a liquid turns into a vapor. The higher the evaporation rate, the more quickly a vapor will be formed. The evaporation rate is compared to a chemical standard, such as butyl acetate or carbon tetrachloride, which has been assigned a rate of 1. For example, isopropyl alcohol, with an evaporation rate of 2.6, evaporates faster than carbon tetrachloride with a rate of 1. Thus, the higher the evaporation rate, the faster the chemical evaporates into the air.

Vapor density is used when describing gases. Vapor density indicates whether a gaseous material is lighter or heavier than air. Air has a vapor density of one. If a gas or vapor has a density of less than one, it will rise; if it has a density greater than one, it will fall. The density of a gas or vapor will indicate where to position an

exhaust. For example, an exhaust for a gas with a vapor density greater than one should be at a low point. This information will help reduce the risk of airborne chemical exposure.

Unfortunately, some chemicals do mix with the air and create health hazards. Once in the air, you may inhale small amounts of a chemical. As a result, you may or may not be affected; however, the MSDS provides health hazard data in Section VI to help you understand the effects of chemical exposure. The information in this section includes routes of entry, type of hazard, carcinogenicity, signs and symptoms of exposure, medical conditions, and emergency and first aid procedures.

We have already described the four ways that a chemical can enter your body - inhalation, skin absorption, ingestion, and injection. We have also focused on inhalation as the route of entry for airborne chemicals. Now, we will turn to other important types of health hazard information, beginning with types of hazards.

Health hazards can be categorized as acute or chronic. Acute effects occur after a short-term exposure and are brief in duration. They are sometimes referred to as immediate health effects. A chemical splashed on the skin may cause an acute reaction such as a skin burn. Chronic effects, however, are adverse health effects resulting from long-term exposure.

Section VI of the MSDS also gives carcinogenicity information. Carcinogenicity means that a chemical is known to cause cancer. There is a list of these chemicals. In addition to the OSHA-regulated carcinogens, the National Toxicology Program and the International Agency for Research on Cancer Monographs are additional references that classify chemicals as carcinogenic.

The section on signs and symptoms of exposure lists warning signs that may indicate that you have been overexposed. For example, if you have inhaled a

particular chemical, then the MSDS should tell you here whether or not exposure causes dizziness or nausea. In some cases, you may not be able to tell whether or not you have been overexposed to an airborne chemical. For example, carbon monoxide is a colorless, odorless gas that displaces oxygen.

The section on medical conditions generally aggravated by exposure will explain the possible health effects that a chemical might have on an existing medical problem. For example, methylene chloride, once absorbed into the blood stream, may create additional stress on an existing heart problem.

Emergency and first aid procedures lists the action to take immediately when an accident occurs. For example, if xylene were to splash in your eyes, you should flush it out immediately with lots of water for at least 15 minutes and then seek medical assistance.

The last required section of the MSDS, Control Measures, Section VIII, lists ways to reduce and prevent exposure to hazardous chemicals, including ventilation, Personal Protective Equipment (PPE), and work and hygienic practices. Ventilation is a good example of an engineering control. Local ventilation, when properly designed, captures and removes contaminants at the point they are produced. This reduces exposure to airborne chemicals.

Personal Protective Equipment (PPE) should be used either where engineering controls cannot be implemented or to supplement existing engineering controls. The MSDS lists four types: respiratory protection, protective gloves, eye protection, and other. Respiratory protection lists the approved type of respirator for a particular hazard. You have to be trained in how to use a respirator properly. If you don't wear the right one or don't use it correctly, you may not be protected.

Protective gloves are necessary when handling certain hazardous chemicals. In most cases, the MSDS will not specify which type to use in each situation. You will have to ask your supervisor what type is appropriate.

Eye protection gives information on the type of eye or face protection, such as splash shields and/or chemical safety glasses. These devices are used when handling a particular substance. Other protective clothing or equipment includes such PPE as aprons or boots.

While Personal Protective Equipment (PPE) can help to reduce the risk of exposure, it does not totally eliminate the risk. PPE for maximum protection against inhalation exposure would be a self-contained breathing apparatus. Picture yourself wearing a SCUBA diving suit while doing your job. This type of protection may not be practical. You might not be able to perform your job at all wearing such protection. And it may not be necessary. PPE may also help in reducing the amount of chronic exposure to a chemical.

Finally, control measures to reduce the risk and exposure to chemicals include work and hygienic practices. They involve such precautions as washing your hands thoroughly, not eating or drinking in an area where a chemical is being used, and removing contaminated clothing.

You, the employee, must be motivated enough for your own protection to learn about the chemicals you work with.

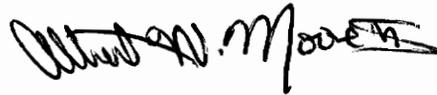
If you were in an accident and you inhaled vapors from an airborne chemical, you would want to know its acute exposure profile. You and your co-workers would also want to know how to provide first aid treatment. On the other hand, if you work with a chemical everyday, all day, you would probably be interested in what long-term or chronic effects are known about the chemical.

Note that the MSDS provides much information. The task is to decode and use it. We've only focused on using the MSDS to recognize airborne exposure risks and ways to control them. The MSDS can be used for this purpose and many others as well. When you return to your job, you are urged to read the particular MSDSs for the chemicals that you work with.

Now that we have discussed some things about airborne exposure risks it is time for some practice.

## VITA

Albert W. Moore II received his B.S. in Industrial Engineering from Virginia Polytechnic Institute and State University in 1988. His current interests include training system development and safety issues.

A handwritten signature in black ink that reads "Albert W. Moore II". The signature is written in a cursive style with a horizontal line at the end.