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# Personal Protective Equipment and Laboratory Safety Training: The Roles of Attitude, Subjective Norm, and Perceived Control

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# PERSONAL PROTECTIVE EQUIPMENT AND LABORATORY SAFETY TRAINING: THE ROLES OF ATTITUDE, SUBJECTIVE NORM, AND PERCEIVED CONTROL

by

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DISSERTATION APPROVAL

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AN ABSTRACT OF THE DISSERTATION OF

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Chemical and biological agents can cause serious adverse occupational health effects, and can adversely impact environmental health. Adverse incidents occur in laboratories using chemical, biological and radiologic agents, and laboratories pose a number of dangers to workers. Adverse incidents occur more frequently in teaching and research institutions when compared to industrial laboratories. Good laboratory safety practices, including the use of personal protective equipment, can reduce the number and severity of laboratory accidents, thus reducing the risk of chemical, biological and radiologic exposure for workers and for the public. Improving laboratory safety training should also result in fewer lab accidents.

This study was conducted at a mid-sized Midwestern research university. The study population consisted of people who had attended a laboratory safety training session in 2010, 2011 or 2012. Following administration of a pilot survey and development of additional items, a sample (N=451) of the total population (N=936) received a survey inquiring about the use of personal protective equipment, and about laboratory safety training. 143 completed surveys were returned.

The survey was based on the Theory of Planned Behavior (Ajzen, 1991). Theoretical constructs investigated included personal protective equipment attitude, subjective norm, behavioral control, behavioral intention, past self-reported behavior, and safety training attitude.

Multiple regression showed that the overall model accounted for 56% of the variability in the study population. Subjective norm was the theoretical construct most strongly predictive of behavioral intention (B=.653, p=.001). Attitude was next most strongly predictive of intention (B=.343, p=.001). Behavioral control was not significantly correlated with behavioral intention. There was a positive significant correlation between training attitude and behavioral intention (Pearson's r = 0.233, p=.006, 2-tailed). There was also a positive significant correlation between attitude toward personal protective equipment, and attitude toward training (Pearson's correlation coefficient was 0.332, p=.001, 2-tailed).

Self-reported behavior was regressed on the three theoretical constructs. Subjective norm was most significantly predictive of self-reported behavior (B = .523, p= .001), followed by attitude (B = .281, p= .034). Behavioral control was not significantly predictive of self-reported behavior.

The study determined that about 80% of respondents felt that their lab was usually or always a safe place to work, although 40% reported having been injured in a lab.

Training can be improved by emphasizing the importance of subjective norm, by clarifying the responsibilities of lab supervisors, and by providing additional information regarding how to obtain, use, and care for personal protective equipment. Use of personal protective equipment may be increased by emphasizing the importance of subjective norm during training.

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# INTRODUCTION

## Background of the Problem

Chemical and biological agents can cause serious adverse occupational health effects, and can adversely impact environmental health. During 2011, the American Chemical Society (ACS) Division of Health and Safety posted information about more than 2,600 chemical accidents worldwide (ACS, 2012). One organization estimates that about 33% of Americans live in areas near chemical facilities which may put them at risk from toxic chemical releases, explosions and fires (Greenpeace, 2012). The most well-known example of this danger was the release of methyl isocyanate gas from a factory in Bhopal, India, in December 1984 which resulted in the death of more than 3,800 people (Broughton, 2005).

Adverse incidents occur in laboratories using chemical, biological and radiologic agents, and laboratories pose a number of dangers to workers. These include chemical hazards, such as carcinogens, toxins and corrosives; biological hazards of infection and injury from bacteria, viruses, and prions; danger of exposure to radioisotopes and other radioactive material; and physical hazards from release of energy, resulting in fires and explosions , according to the Occupational Safety and Health Administration (OSHA, 2012).

Adverse laboratory incidents occur more frequently in teaching and research institutions when compared to industrial laboratories. Estimates of the frequency of these incidents in school and college laboratories have been reported to be 100 to

1,000 times greater than the frequency seen in industrial laboratories (Laboratory Safety Institute, 2012).

Between December 2008 and February 2012 in the United States there were at least eleven major laboratory incidents in postsecondary educational institutions, causing property damage, injuries and explosions. The United States Chemical Safety Board has "gathered preliminary information on 120 different university lab incidents since 2001" (Trager, 2011, p. 6).

Good laboratory safety practices, including the use of personal protective equipment, can reduce the number and severity of laboratory accidents, thus reducing the risk of chemical, biological and radiologic exposure for workers and for the public. Scientists learn and establish safety practices during their years of study at post-secondary institutions, and carry those safety habits into their professional careers. Improving ways in which laboratory safety is taught is important to the future health and safety of society.

## Statement of the Problem

Training in safe handling of chemicals, biological agents, and radioisotopes is required by regulatory agencies, including OSHA and the Environmental Protection Agency (EPA) before workers handle these hazardous materials. Most educational institutions mandate some kind of safety training before faculty, staff and students work in laboratories, and also require annual refresher training (National Research Council, NRC, 1995; Environmental Compliance Assistance Guide, 2002). Despite training, however, it seems that too often lab safety is compromised, both in educational and industrial institutions, resulting in environmental damage, property loss, personal injury, and even death (ACS, 2002; Hill, 2003).

## Need for the Study

The U.S. Census Bureau ("Current population survey," 2012) estimates that more than 20 million people are enrolled in undergraduate and graduate studies, and the National Science Board (2012) estimates that about one third of those people will major in science and engineering programs. When coupled with standard requirements for two or more science classes as general education classes for undergraduates, it appears that as many as 7 to 8 million postsecondary students may be involved in laboratory work with chemicals, biologic agents and radiologic agents each year in the U.S. (National Center for Education Statistics, 2012). OSHA (2012) reports that more than 500,000 people are employed in laboratories in the United States. Thus, the number of people working in laboratories and at risk for unintended injury is large.

Most postsecondary educational institutions provide faculty, staff and students with laboratory safety training. It's delivered in a variety of ways: an introductory safety lecture when students first begin work in the lab (Alaimo et al., 2010), safety games (Helser, 1999; Gublo, 2003); comics (DiRaddo, 2006); and videos (Matson et al., 2007). Some institutions have a separate undergraduate laboratory safety course (Nicholls, 1982). A common factor in all these kinds of training is instruction regarding the appropriate use of personal protective equipment, particularly lab coats, eye protection and glove use (NRC, 1995).

In spite of the instruction given to laboratory workers, it has been reported for many years that "…student lab practices and attitudes toward safety were sometimes deficient…students were bored by the litany of lab safety rules and brief prelab safety notes" (Alaimo et al, 2010, p. 856). Gublo (2003) characterized the safety seminars as "…boring and repetitive" (p. 425). Yet this information is absolutely vital to the health and safety of laboratory workers, both during their time in educational institutions, and during their careers.

To date, I have been unable to find any studies which examine laboratory workers' attitudes toward personal protective equipment, and toward laboratory safety training. Understanding these attitudes may help us to improve laboratory safety training programs and the use of personal protective equipment. Improved training and practices should reduce the danger of unintentional release of hazardous agents, reduce environmental pollution, and reduce hazards to laboratory workers and to the population in general.

## Significance of the Study

Occupational safety and health is one of the topic areas of Healthy People 2020 (U.S. Department of Health and Human Services, 2011). Environmental health is another topic of Healthy People 2020, and one of the six themes within the environmental health area refers to toxic substances and hazardous waste. Toxic substances and hazardous waste are addressed in the standard laboratory safety training at most postsecondary institutions, because they are common in a laboratory setting (Prudent Practices, 2002; OSHA, 2012).

The results of this study might be used to improve training in terms of personal protective equipment, and improved training should result in reduced morbidity and mortality due to hazardous chemical and biological exposure among workers, as well as reduce environmental contamination.

Postsecondary educational institutions have a responsibility to "...nurture basic attitudes and habits of prudent behavior in the laboratory so that safety is a valued and inseparable part of all laboratory activity" (NRC, 1995, p.16). We need a deeper understanding of the factors involved in use of personal protective equipment in order to improve the teaching of scientific safety, and to reduce chemical, biological and radiologic hazards to workers, the population, and the environment.

## Purpose of the Study

The purpose of the study was to examine attitudes, subjective norms, behavioral control, behavioral intention, and self-reported behaviors of laboratory personnel in a postsecondary educational institution regarding personal protective equipment in laboratories, and to examine attitudes of laboratory personnel in a postsecondary educational institution regarding laboratory safety training. Many safety programs, particularly those developed for industrial settings, rely primarily on reducing people's unsafe actions through development of standard operating procedures, provision of safety equipment, and use of engineering controls; these programs emphasize only the physical aspects of the activity. However, human factors, including attitude, play a role in unsafe behavior (Fogarty and Shaw, 2010). The National Institute for Occupational Safety and Health (NIOSH) sponsored a review of training effectiveness and concluded, among other things, that there were too few studies which addressed people's attitudes regarding safety training (Robson et al., 2010). When Trifiletti, Gielen, Sleet & Hopkins (2005) conducted a study of the use of behavioral and social sciences theories and models in unintentional injury prevention research, they stated "...when behavioral and social sciences theories and models were applied to unintentional injury topics....few examples of theory testing were found" (p. 298). This study was intended to help fill that gap.

Attitudes, subjective norms, perceived control, behavioral intention, and self-reported behaviors toward use of personal protective equipment, and attitudes regarding laboratory safety training, were examined utilizing a theoretical framework – the Theory of Planned Behavior (Ajzen, 1988, 1991). Testing this theory through examination of the use of personal protective equipment and safety training should have these beneficial results: first, we should be able to understand more clearly why people may not use personal protective equipment in laboratories. Second, it should help us to design more effective training to prevent unintentional injuries in laboratories.

## Theoretical Framework

The Theory of Planned Behavior is one of the most frequently used theoretical models for unintentional injury prevention (Sleet, Trifiletti, Gielen, & Simons-Morton, 2006). It is an extension of the Theory of Reasoned Action (Ajzen & Fishbein, 1980).

The Theory of Planned Behavior (Ajzen, 1991) proposes that the most important predictor of behavior – many kinds of human behavior, across many disciplines – is behavioral intention. Behavioral intention is formed by three behavioral constructs: the attitude toward the behavior, subjective norm, and perceived behavioral control (Montano, Kasprzyk & Taplin, 1997).

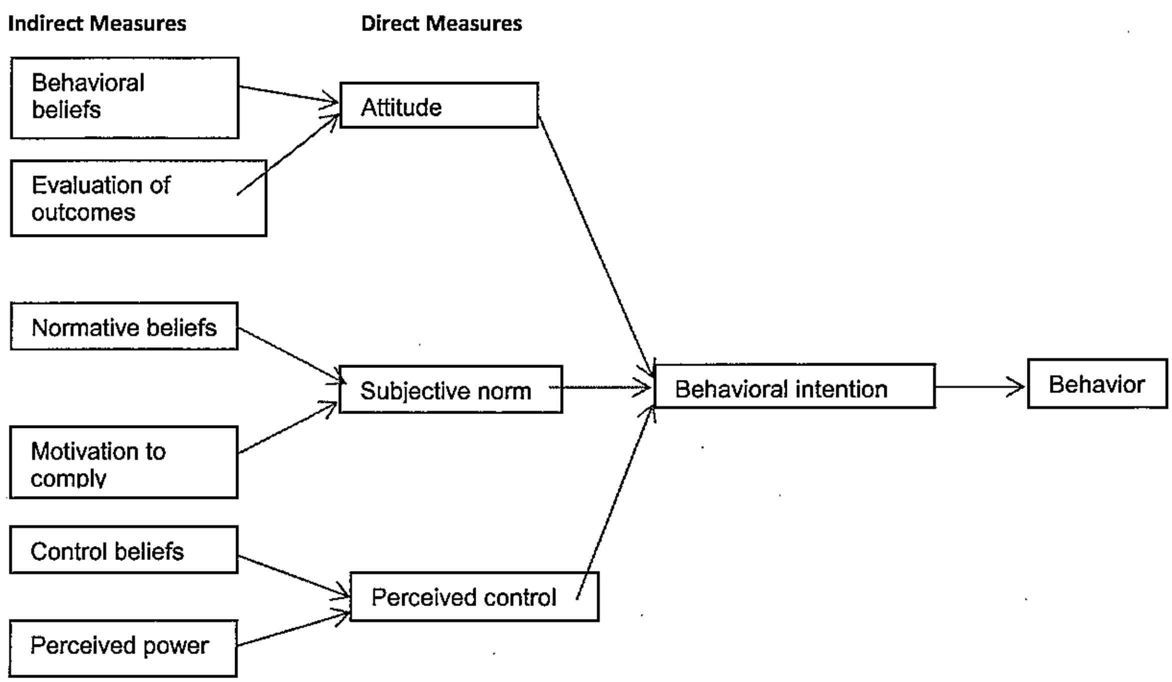


Figure 1.

*Ajzen's Theory of Planned Behavior*

This study explored attitude, subjective norm, perceived behavioral control, self-reported behavior, and behavioral intention in terms of use of personal protective equipment, and attitude toward laboratory safety training. These constructs were measured using a questionnaire constructed according to published guidelines (Fishbein & Ajzen, 2010).

## Research Design

The study was designed as a cross-sectional descriptive study. This type of study provides a kind of snapshot in time, across a defined population (Isaac & Michael, 1981). The study was designed to determine direct measurements of attitude, subjective norms, perceived behavioral control, self-reported behavior, and behavioral intention with respect to use of personal protective equipment in laboratories; indirect measurements of attitude, subjective norm and perceived behavioral control with respect to use of personal protective equipment; and direct measurements of attitude toward laboratory safety training.

The setting for the study was a Midwestern, middle-sized postsecondary educational institution that had a strong emphasis on scientific research. SIUC has at present about 700 laboratories, with some 600 scientists employed by the school. Up to 5,000 students per semester are enrolled in laboratory courses. The school was listed by the Carnegie Foundation for the Advancement of Teaching as a high research activity institution, and is among the top 4% of U.S. institutions for higher education in terms of research (SIU Carbondale, 2012).

## Research Questions

The study seeks to answer these questions:

1. Can the three constructs in the Theory of Planned Behavior – attitude, subjective norm and perceived behavioral control – be used to predict behavioral intentions with respect to use of personal protective equipment in laboratories?

2. What is the relationship between measures of attitude toward laboratory safety training, and behavioral intention in terms of use of personal protective equipment?

3. What is the relationship between attitude toward use of personal protective equipment, and attitude toward laboratory safety training?

4. What is the relationship among demographic variables, and the constructs of attitude, subjective norm, and perceived behavioral control, with respect to use of personal protective equipment?

5. Can the three constructs in the Theory of Planned Behavior – attitude, subjective norm and perceived behavioral control – be used to predict self-reported behavior with respect to use of personal protective equipment in laboratories?

**Sample**

The population from which the sample was drawn includes all people who attended laboratory safety training workshops at SIU Carbondale in 2010, 2011 and 2012 and who were still associated with the University as an employee or student at the time of the study. Each person who works in a laboratory – faculty, staff, graduate students, and undergraduate students – must attend annual laboratory safety and hazardous waste disposal training. This training is mandated by EPA and by OSHA; it is a live presentation, and takes about an hour. I designed the training curriculum, and I present the training to the audience through lecture and Power Point™. The training includes information regarding regulations applicable to the use of chemical and biological agents; physical hazards and health hazards of laboratory work; mandated laboratory safety practices and procedures; appropriate use of personal protective equipment including lab coats, glove protocol and eye protection; and correct handling and disposal of hazardous chemical and biological waste.

Attendees at the training sessions complete a sign-in sheet, including their names and departments. The sign-in sheets for all the annual training workshops for 2010, 2011, and 2012 were combined to yield the population of study. The population was divided according to employment status – faculty, staff, graduate student and undergraduate students – and a random sample was selected proportionately from each category. Thus, the study utilized a stratified random sample design. This design should allow the results to be generalizable to different academic populations (Hibberts, Johnson & Hudson, 2012).

## Instrumentation

The instrument was designed as described by Azjen (2012) using the Theory of Planned Behavior. The pilot instrument was designed to measure attitude, subjective norms, perceived control, past behavior, and behavioral intention respecting use of personal protective equipment, and measure attitude and subjective norms toward laboratory safety training. The pilot test also included open-ended items to elicit information regarding behavioral beliefs, normative beliefs, and control beliefs. The information acquired from responses to the open-ended items in the pilot test was used to design additional items; these additional items were included in the final survey, which tested indirect measurements of attitude, subjective norm and perceived control with reference to use of personal protective equipment, as well as all the items for direct measurement in the pilot survey. Indirect measurements were included in the final instrument to help improve validity (Ajzen, 2012).

## Data Collection and Analyses

The survey was conducted utilizing paper and pencil. Although more time-consuming than electronic surveys, this standard method was chosen for its increased response rate compared to electronic surveys (Crouch, Robinson and Pitts, 2010). Completed surveys were accepted for three weeks following distribution. Responses were entered into an Excel™ spreadsheet and analyzed with IBM's product Statistical Package for the Social Sciences Data Collection™ program. Pearson's correlation coefficient was used to study the relationship between demographic data and attitude, subjective norm, and perceived behavioral control with reference to use of personal protective equipment, and between demographic data and attitude toward chemical safety training. Multiple regression was used to determine the amount of variance in the population accounted for by the constructs of attitude, subjective norm, and perceived behavioral control with reference to use of personal protective equipment. Survey instruments were eliminated from the study if the respondent answers fewer than 95% of the questions.

## Assumptions

The following assumptions were made with respect to the study:

1. The survey instrument was valid and reliable.
2. The participants understood and followed the directions.

3. The participants understood each item in the instrument.
4. The participants answered honestly.
5. The survey instrument accurately measured the variables of interest.

## Limitations

Limitations of a study are those things which a researcher cannot control, and may limit the ability to infer results and conclusions from one population to another. Limitations of this study include:

1. Due to response bias, people who were interested in, or knowledgeable of, laboratory safety may be over-represented in the study's responding populace.
2. The stratified random sample may not be representative of the larger population.
3. Surveys distributed by mail did not allow the participants to ask questions if something was unclear to them.

## Delimitations

Delimitations of a study are those limits which are imposed by the researcher. For this study, they include:

1. The sample of the population was limited to those people who attended one of the annual chemical safety and hazardous waste disposal workshops at SIUC in 2010, 2011 and 2012, and who were still associated with the University as faculty, staff or student at the time of the study.
2. The study measured behavioral intent and self-reported behavior; it did not measure actual behavior.

## Definition of Terms

The following operational definitions were used in this study:

*Attitude*: A learned predisposition to respond in a consistently favorable or unfavorable manner with respect to a given object (Fishbein & Ajzen, 1975, p. 6). The same source also says, "...the meaning of a concept is defined in terms of its relations to other constructs in a theoretical network" (p. 5). Thus, *attitude* in the Theory of Planned Behavior can be defined as *behavioral beliefs* modified by *evaluation of outcomes* (Montano, Kasprzyk & Taplin, 1997).

*Behavioral beliefs*: "...a person's subjective probability judgments concerning some discriminable aspect of his world" (Fishbein & Ajzen, 1975, p. 131).

*Chemical hazard information*: The term includes information available on the labels of chemical containers, on Safety Data Sheets (formerly known as Material Safety Data Sheets, or MSDSs), and in various reference books, particularly *Prudent Practices in the Laboratory* (National Research Council, 1995), *Safety in Academic Chemistry Laboratories* (American Chemical Society, 1990), and *Bretherick's Handbook of Reactive Chemical Hazards* (1990). These three reference books are common to many laboratories.

*Control beliefs*: "...the presence or absence of resources for, and impediments to, behavioral performance" (Montano et al., 1997, p. 92). Control beliefs, modified by perceived power, form the construct of perceived control (Ajzen, 1985).

*Evaluation of outcome*: The strength of a positive or negative value for a given behavioral belief (Ajzen & Fishbein, 1980).

*Motivation to comply*: The strength of the desire to perform or not perform a given behavior which is approved or disapproved by an important referent individual or group (Ajzen & Fishbein, 1980).

*Normative beliefs*: "Normative beliefs are concerned with the likelihood that important referent individuals or groups approve or disapprove of performing a given behavior" (Ajzen, 1991, p. 195).

*Perceived control*: "...perceived behavioral control refers to people's perception of the east or difficulty of performing the behavior of interest" (Ajzen, 1991, p. 183).

*Perceived power*: The strength of a positive or negative value for a given control belief (Ajzen, 1991).

*Subjective norm*: "...refers to the perceived social pressure to perform or not perform a behavior" (Ajzen, 1991, p. 188).

## Scientific Organizations Acronyms

Repeated references are made throughout this document to a number of scientific organizations which are usually referred to by their initials. Following is a list of the organization and the initials to which it will be referred, with a brief description of each organization.

*ACS*: American Chemical Society. A private membership organization chartered by the U.S. Congress, ACS is the largest scientific society in the world, serving members in all fields of chemistry, and in fields related to chemistry (ACS, 2012).

*EPA*: Environmental Protection Agency. A Federal agency established by the U.S. Congress in 1970, this agency promulgates rules and regulations to protect human health and the environment (EPA, 2013).

*NIOSH*: National Institute for Occupational Safety and Health. Part of the Centers for Disease Control and Prevention, NIOSH is a Federal agency which is responsible for conducting research and making recommendations for the prevention of workplace-related injury and illness (CDC, 2013).

*NRC*: National Research Council. The NRC is one of four National Academies, private nonprofit institutions that provide advice and information about science, engineering and medicine (NRC, 2013).

*OSHA*: Occupational Safety and Health Administration. A Federal agency established by the U.S. Congress in 1970, this agency is part of the U.S. Department of Labor, and was established to help provide safe and healthy working conditions by setting and enforcing standards ( U.S. Department of Labor, 2013).

## Summary

Explosions, fires and chemical releases from laboratories in post-secondary institutions are a matter of great concern (U.S. Chemical Safety Board, 2011). There is little research to count or categorize these incidents, since there is no mandated national reporting required. These incidents can result in unintentional chemical release, environmental damage, unintentional injury, and even death. It is suspected that the frequency of these incidents is much greater than similar incidents in private industry (Laboratory Safety Institute, 2012). This study investigated the roles of attitude, subjective norm, perceived behavioral control, past behavior, and behavioral intention for use of personal protective equipment, and the relationship between attitude toward laboratory safety training and behavioral intention regarding use of personal protective equipment. The study may help us to identify areas for future intervention to reduce unintentional injury in laboratories.

Chapter One has introduced the problem, described the aims of the research, and described the methods of study. Chapter Two discusses the current literature regarding regulatory compliance, safety training, the Theory of Reasoned Action, and other topics related to the study.

# CHAPTER 2

# REVIEW OF LITERATURE

The previous chapter described the problem of unsafe laboratory behavior and its adverse consequences on occupational health and on environmental health. Regulations which govern these laboratories require that personnel receive training for chemical, biological and radiologic hazards. In spite of these training programs, dangerous incidents still occur nationwide in academic laboratories. I have been unable to find any study to date which assesses laboratory safety training programs, and only one study which examined use of personal protective equipment in terms of a theory of behavior. This chapter reviews the current literature in areas applicable to this study: recent adverse laboratory incidents; hazards in laboratories; protections to control hazards; personal protective equipment; cost of adverse incidents; history and teaching of laboratory safety; regulation of laboratories; the theoretical model; and other behavioral models.

## Recent Adverse Laboratory Incidents

In September 2008, the death of a professor at the University of Chicago from plague, with which he was conducting research, was recorded (Hu, 2008). Three months later, in December 2008, a 23-year-old graduate student at the University of California Los Angeles (UCLA) was severely burned when working with an air-reactive chemical, and she died 18 days later (Christensen, 2011). An explosion at a lab at Texas Technical University on January 7, 2010 cost a graduate student the loss of three fingers on his left hand and the sight of his left eye ("CSB releases investigation," 2011). There was an explosion in a laboratory at the University of Missouri in June, 2010 that injured four people (Jain, 2010). The same month, Southern Illinois University Carbondale suffered a major fire in a research laboratory, resulting in more than $1 million in damages (Kemsley, 2010). In April 2011, a Yale undergraduate student died in a chemistry laboratory machine shop (Shaw, 2011). By September 2011, a researcher from the University of Chicago had been hospitalized following an exposure to an infectious organism in her lab (Kaiser, 2011). The same year, an explosion in an organic chemistry lab at the University of Maryland sent two students to the hospital with burns (Kemsley, 2011), and there was another fire at UCLA ("Fire extinguished," 2011). In October 2011 there were two explosions within two weeks at Texas Tech (Young, 2011). That same month, an explosion occurred in a lab at the University of Florida, and another explosion in the same lab with the same chemical injured a graduate student in January 2012 (Crabbe, 2012). The following month, five students and a lab tech were injured in an explosion at South Carolina State University (Santaella, 2012). In late April 2012, a 25-year-old laboratory worker in the San Francisco Veteran's Affairs medical center died from meningitis acquired when working with a strain of the bacteria (MacKenzie, 2012).

The Chemical Safety Board conducted an investigation of the explosion at Texas Tech in 2010, and issued the final report of the incident in October 2011 (U.S. Chemical Safety Board, 2011). They recommended that the Occupational Safety and Health Administration develop a bulletin to describe the need to control physical hazards in laboratories, and recommended that the ACS develop a good practices document to help guide laboratories. The ACS then formed a task force which issued a report entitled *Creating Safety Cultures in Academic Institutions* (2012). The executive summary of the report began "Devastating incidents in academic laboratories and observations, by many, that university and college graduates do not have strong safety skills, have elevated concern about the safety culture in academia" (p. 6). The report discusses what a safety culture is, the need for a culture of safety in academia, and recommendations for the creation of such a culture.

## Hazards in Laboratories

Certain classes of laboratory agents pose dangers to workers and to the environment (OSHA, 2010). These agents can include carcinogens, toxins and toxin-producing organisms, corrosives, sensitizers, irritants, cryogenic compounds, compressed gases, reactive compounds, radioisotopes, polymerizable materials, peroxide-forming compounds, nonionizing radiation, electrical or magnetic hazards, and work done under vacuum or high pressure (NRC, 1995).

Carcinogens are chemicals which are or may be associated with the development of carcinoma in humans, and can be the result of chronic exposure (NRC, 2011). A number of national and international agencies issue lists of known or suspected human carcinogens. One such agency is the International Agency for Research on Cancer, known as IARC; it is an agency of the United Nations World Health Organization (Boyle & Levin, 2008). IARC uses a classification system which divides agents into one of five groups. Group 1 agents are definitely carcinogenic to humans; Group 2A agents are probably carcinogenic to humans; Group 2B agents are possibly carcinogenic to humans; Group 3 agents cannot be classifiable as to carcinogenicity; and Group 4 agents are probably not carcinogenic to humans (Boyle & Levin, 2008). Another agency which reports classifications of carcinogenicity is the National Toxicology Program (NTP), a part of the U.S. Public Health Service, which is an agency of the U.S. Department of Health and Human Services (NRC, 1995). NTP is mandated to issue a biennial Report on Carcinogens to the U.S. Congress (NTP, 2012). Their classification system uses only two groups: agents which are known to be human carcinogens, and agents which are reasonably anticipated to be human carcinogens. One more important group which addresses carcinogenicity is the American Conference of Governmental Industrial Hygienists, or ACGIH (Furr, 1990). ACGIH is a private organization, and it's most widely known for the use of a measurement called Threshold Limit Value, or TLV, which is the upper recommended limit of carcinogen exposure on a daily basis (Meyer, 1989).

Toxicity is a characteristic of many substances, including water; the relative toxicity of an agent depends upon the amount to which one is exposed; the amount of time of exposure; the route of exposure, whether inhaled, ingested, absorbed, or injected; and other personal factors (ACS, 2003). A toxin can be defined as a poison which in small doses can cause adverse health effects, including death (Meyer, 1989). Many chemicals can be considered as toxins, and some pathogenic microorganisms release toxins, causing adverse effects in humans or animals (Tepper & Gilpin, 2002).

Corrosive chemicals are those which can cause damage to living tissue during contact, and may cause fires when in contact with organic matter (Furr, 1990). Corrosive substances pose a danger not only to skin and eyes, but also to respiratory tracts and sometimes to digestive tracts (NRC, 1995). Corrosive substances can be found in all states of matter: solids, liquids and gases (Meyer, 1989). Strong acids and bases are commonly considered to be the largest classes of corrosives, but other agents can also be included as corrosives, such as dehydrating agents and oxidizing agents (Furr, 1989). Examples of dehydrating agents include phosphorus pentoxide and calcium oxide; oxidizing agents which present corrosive hazard include calcium hypochlorite and hydrogen peroxide.

Sensitizers are those chemicals which upon first exposure cause little or no effect, but upon repeated exposure may elicit strong reactions, either locally or systemically (Gorman, 1993). Sensitizers and allergens are terms which can be used interchangeably, and may also be referred to as hypersensitivity (NRC, 1995). Development of sensitivity to animal allergens is particularly problematic when conducting work with mice and rats, and is of concern to animal care workers (NRC, 2011).

Irritants are defined as agents that cause local, short-term adverse effects, either from short-term or chronic use (Meyer, 1989). They are generally classified as noncorrosive agents for which inflammatory effects are reversible (NRC, 1995).

Cryogens are agents or processes that deal with very low temperatures; usually they are defined as those agents or processes below -100°C to differentiate them from refrigeration (Furr, 1990). Cryogenic conditions are often achieved by using liquefied gases, particularly liquid nitrogen and helium (Bretherick, 1990). These liquefied gases retain the hazards they presented when not liquefied, such as corrosivity or toxicity, and present additional hazards, including the ability to displace oxygen from the atmosphere acting as an asphyxiant (ACS, 2003). Cryogens have the ability to liquefy other gases, including oxygen and air, which can present an explosion hazard, and cryogens are extremely damaging to living tissue (Meyer, 1989).

Compressed gases are frequently used in laboratories; in addition to the hazards presented by the gases themselves, such as corrosivity or reactivity, hazards exist due to the high pressure under which the gases are stored and used (ACS, 2003). The Compressed Gas Institute (OSHA, 1965) has published a useful guide to safe handling and storage procedures for compressed gases. They recommend that cylinders be restrained or secured from tipping or falling to prevent damage to the valve. Damaged valves may fail, resulting in catastrophic release of energy (NRC, 1995). Storage and use of flammable gases, like acetylene or hydrogen, are strictly regulated by local fire authorities (National Fire Protection Association, 2012).

Reactive agents include compounds that are air- or water-reactive, agents or conditions that can explode, and agents that can explosively polymerize (Bretherick, 1990). Reactive agents often are involved in processes which can lead to greatly increasing reaction rates, leading to explosions (NRC, 1995). Reactive metal compounds, such as sodium, lithium and potassium, present special flammability hazards, since they may react with water in the atmosphere to produce flammable gases; these compounds are water-reactive, and will explode if a water-based fire extinguisher is used to quench a reactive metal fire (Furr, 1990). Air-reactive chemicals are also called pyrophorics; they react with oxygen or water in the air immediately upon exposure and ignite, sometimes violently (NRC, 1995). Air- and water-reactive compounds are rarely used in teaching laboratories because of the danger they present, but are used in research laboratories (ACS, 2003). An unintentional spill of a pyrophoric compound, tert-butyl lithium, resulted in the death of a researcher at UCLA in 2009 (Trager, 2011).

Radioisotopes are most commonly used in research laboratories in the life sciences, to trace biological energy pathways, and in the diagnosis and treatment of certain diseases in medical research laboratories (Meyer, 1989). Radioisotopes undergo spontaneous decay, resulting in the release of particles or radiation that can be damaging to living tissue (Furr, 1990). One useful property of radioisotopes is that their rate of decay is not affected by physical conditions, such as changes in temperature or pressure (Meyer, 1989). Acquisition, use and disposal of radioisotopes are heavily regulated by state agencies under the authority of the Nuclear Regulatory Commission; in Illinois, the agency is the Illinois Emergency Management Agency, or IEMA (2012).

Nonionizing radiation includes ultraviolet, visible, and near-infrared radiation from lamps and lasers, and radiofrequency and microwave radiation from ovens, heaters and inductive furnaces (NRC, 1989). These kinds of radiation pose threats primarily to eyesight (ACS, 2003). Lasers are classified by the manufacturer as Class I, II, III or IV, with higher class numbers indicating more powerful lasers (Furr, 1990). X-ray machines and lasers are sometimes referred to as "sealed sources" and in Illinois they are regulated by the Illinois Emergency Management Agency (IEMA, 2012).

Polymerizable materials are those substances that exist as monomers, or single-unit molecules, and under certain conditions these monomers can combine to form polymers, or linked units, with an explosive release of energy (Meyer, 1989). Bretherick

(1990) lists more than 50 compounds that have been reported to explosively polymerize. Compounds that may polymerize explosively must be carefully handled and stored away from agents or conditions that act as initiators (Furr, 1990).

Peroxide-forming compounds are those substances that, after exposure to air, begin to form straight-line oxygen-oxygen bonds called peroxides (Furr, 1990). Peroxides can cause the compound to become shock-sensitive, and the bottle may explode when moved or when someone tries to remove the cap (NRC, 1995). Peroxides may be formed in some types of ethers, and in tetrahydrofuran, a common solvent (Bretherick, 1990). Most peroxide-forming compounds have an expiration date on the label, typically a year from the time the compound was produced, but formation of peroxides can be hastened as the bottle becomes less full, since more air is present in the bottle to react with the compound (Furr, 1990).

Electrical and magnetic hazards are common in many kinds of laboratories. Furr (1990, p. 323) says "...most of the hazards associated with the use of electricity stem from electrical shock, resistive heating, and ignition of flammables..." Common electrical equipment found in laboratories includes "...fluid and vacuum pumps, lasers, power supplies, both electrophoresis and electrochemical apparatus, x-ray equipment, stirrers, hot plates heating mantles, and, more recently, microwave ovens and ultrasonicators" (NRC, 1995, p. 109). All electrical outlets in laboratories must have grounding connections, and all electrical equipment must have 3-prong plugs for grounding; OSHA has included many parts of the National Electrical Code in its regulation 1910 Subpart S, Electrical (Furr, 1990).

Vacuum (low-pressure) and high pressure work occur in laboratories, and "…for many experiments, extremes of both pressure and temperature…must be managed simultaneously" (NRC, 1995, p. 126). Chambers called pressure vessels, such as a steam autoclave, are designed to withstand high pressure and high temperature (Furr, 1990). The primary danger associated with work at high or low pressure is the failure of the containment vessel, with subsequent implosion or explosion which can result in injury and destruction (NRC, 1995).

Biological agents pose a threat to workers, and can pose a threat to the population at large if the agent is potent and is released, either intentionally or unintentionally, to the environment (NRC, 1989). Biological agents can include living organisms such as bacteria and fungi; non-living biological agents such as viruses and prions; and toxins produced by biological agents (U.S. Department of Health and Human Services, 2009). Biological safety is the topic of the seminal work in the area, the *book Biosafety in Microbiological and Biomedical Laboratories* (U.S. Department of Health and Human Services, 2009) which is often referred to simply as the BMBL. This manual assigns biological agents to Biosafety Levels 1 through 4, with lower-risk organisms assigned lower numbers, and describes recommended handling procedures for various biosafety levels. One important subset of biological agents include recombinant DNA, or rDNA; that is, "…molecules which are constructed outside living cells by joining natural or synthetic DNA segments to DNA molecules that can replicate in a living cell…"(NIH Guidelines, 1986). The Guidelines classify work with rDNA into one of four classes, Class III-A, III-B, III-C and III-D; Class III-D agents are exempt from the Guidelines, while Class III-A work requires the approval of the Federal Recombinant

DNA Advisory Committee, as well as approval by NIH and the local Institutional Biosafety Committee (Furr, 1990). The Guidelines require that any institution working with rDNA establish an Institutional Biosafety Committee, which is charged with reviewing and approving protocols for work with rDNA (Tepper & Gilpin, 2002).

Following the terrorist attacks in the U.S. on September 11, 2000 and the subsequent terrorist attacks utilizing weaponized anthrax, the Federal regulations regarding select agents were reviewed, updated and expanded in 2002 (Agricultural Bioterrorism, 2012). These regulated agents include anthrax, smallpox, and plague, and pose a threat to human, animal and plant health and safety (Kastermayer, Moore, Bright, Torres-Cruz & Elkins, 2012). Use of these agents in research is limited to institutions that have registered with either the U.S. Public Health Service or the Animal and Plant Health Inspection Service (APHIS) of the U.S. Department of Agriculture; have conducted a risk assessment and filed a security plan; and have appropriate containment facilities, including access to a Biosafety Level 3 or 4 laboratory, depending upon the ranking of the agent (Agricultural Bioterrorism, 2012).

A number of safety issues are posed by work with animals in laboratories. Institutions which receive Federal funding and work with animals must establish an Institutional Animal Care and Use Committee, or IACUC, to oversee all research-related animal work (NRC, 2009). The committee is charged with reviewing protocol proposals from researchers and approving the work before research can begin; the work must be in compliance with the Office of Laboratory Animal Welfare rules and regulations (Gonder, Smeby & Wolfle, 2001). These regulations also require that the institution establish an occupational health and safety plan for work with animals; it requires risk assessment and hazard identification. Common hazards of work with animals include possible exposure to biologic agents such as viruses and bacteria; exposure to chemical agents such as carcinogens or mutagens; physical risks of sharps exposure from work with needles and syringes; the possibility of animal bites; possible exposure to radiation, such as radioisotopes, X-rays or lasers; and exposure to allergens (NRC, 2009). Another complication of animal work can be the risks associated with using immunocompromised or genetically modified animals. Severely compromised immunodeficient mice, or SCID mice, are susceptible to or may shed human pathogens, and pose a particular risk when used with human tissues or cell lines (NRC, 2009).

## Protection to Control Laboratory Hazards

For most regulations regarding employee safety, OSHA mandates a hierarchy of hazard control; the agency mandates that employers first use engineering controls and administrative controls to remove or reduce hazards in the workplace, and only then should rely on the use of personal protective equipment (NRC, 2009). All three methods of hazard control will be discussed in reference to routes of exposure to various hazards.

The four standard routes of exposure to a chemical or biological agent are inhalation, absorption, ingestion, and injection (Furr, 1990). Engineering controls, or equipment to remove or reduce the hazard in the workplace, for inhalation danger in laboratories consist primarily of ventilation devices like chemical fume hoods, biosafety cabinets, and local ventilation devices like snorkels for fume hoods (NRC, 1995).

Chemical fume hoods are simple "air in – air out" devices to remove fumes, vapors and gases from the workplace, particularly from the breathing zone of workers (Furr, 1990). Chemical fume hoods are intended for work with flammable and corrosive chemicals. Biosafety cabinets are another kind of ventilation device, and are intended for work with bacteria, viruses, cell lines, and other microbes (NRC, 1995). Biosafety cabinets filter air from the cabinet through a particulate filter and a carbon filter to remove microorganisms; they work to keep a sterile environment inside the cabinet and also in the laboratory by confining microbes (Furr, 1990). Ventilation devices also work to reduce absorption of hazardous material; proper use of fume hoods and biosafety cabinet prohibits placing one's head in a cabinet, and reduces placement of arms to a minimum (NRC, 1989).

An engineering control for ingestion hazard could be the use of a surgical mask; although surgical masks do not protect the wearer against significant inhalation exposure, they may act to remind the user to avoid touching their face and mouth when working with hazardous agents (Furr, 1990). An example of an engineering control for injection exposure is use of a sharps container, which is a rigid, puncture-proof container for the disposal of needles, syringes, and scalpels (U.S. Department of Health and Human Services, 2009).

Administrative controls for reducing hazards in laboratories generally consist of good laboratory practices (OSHA, 2010). For all types of chemical and biological exposure, risks can be reduced by working with the smallest amount of agent possible (NRC, 1995). Administrative policies can reduce the risk of many kinds of exposure by forbidding mouth pipetting; forbidding eating, drinking, smoking, applying makeup or contact lenses in laboratories; by mandating proper glove protocol to reduce contamination risks; by forbidding shorts, sandals or open-toed shoes in laboratories; and by mandating appropriate use of personal protective equipment (OSHA, 2010).

Other administrative and engineering controls can be used to reduce hazards in laboratories. One useful set of tools include proper inventory management and proper storage practices for chemical and biological agents (NRC, 1995). Minimizing the amount and number of chemicals and biological agents ordered and stored will result in reduction of risk of exposure and spills (OSHA, 2010). Proper storage of chemicals mandates storing incompatible chemicals separately, to reduce the risk of unintended reactions or releases (Furr, 1990).

Two useful pieces of laboratory safety equipment that qualify as engineering controls include safety showers and eyewash stations (OSHA, 2010). Safety showers act to quickly wash off hazardous chemicals or biological agents, and to quench clothing fires (Furr, 1990). Eyewash stations can be used to rinse eyes after exposure to chemical agents, biological pathogens, or after blood or body fluid exposure (NRC, 1995).

## Personal Protective Equipment

Personal protective equipment is considered to be the last line of defense against exposure to many substances in laboratories (Furr, 1990). When engineering and administrative controls cannot reduce risk of inhalation to acceptable levels, employees may wear respirators; however, a separate OSHA respiratory standard controls use of respirators. This standard requires that respirator users must have medical approval to wear a respirator; must be fit-tested annually to insure protection; and requires that employers provide employees with the appropriate style of respirator, ranging from disposable dust-and-mist masks, through half-face or full-face filtering respirators, powered air-purifying respirators, half-face and full-face filtering respirators, to self-contained breathing apparatus (Furr, 1990).

Personal protective equipment to protect against absorption and injection include protective laboratory coats or gowns, gloves, and eye protection (OSHA, 2010). Lab coats can protect workers against skin and clothing contact with chemical and biological agents; flame-resistant lab coats can reduce the hazards of burns, while splash-resistant lab coats can reduce the hazards of liquid exposure, including exposure to corrosive chemicals, pathogenic organisms, and blood or other body fluids (Furr, 1990). Eye protection can include impact-resistant safety glasses; safety goggles for use with corrosive or flammable liquids; and full-face shields (NRC, 1995).

There are a number of peer-reviewed publications which discuss the use of personal protective equipment for industrial settings, such as recommendations for the nanotechnology industry (Greaves-Holmes, 2009; Ling, Wang, & Pui, 2012). The majority of peer-reviewed published work about personal protective equipment in laboratories comes from the medical setting; I found only one publication that described personal protective equipment in a non-medical laboratory, which was a discussion of single-use dissolvable lab coats tested in a nuclear facility (Cournoyer, Wannigman, Lee, Garcia, Hase, George, Wilburn & Schreiber, 2012).

O'Brien (2008) provides a good overall discussion of the regulatory requirements for personal protective equipment in healthcare settings, including a tool for hazard assessment. Hinkin, Gammon & Cutter (2008) published a review of personal protective equipment used by community nurses, and report that although the proper use of personal protective equipment is a cornerstone of infection control for bloodborne pathogens, compliance with requirements for correct glove protocol is "...less than optimum" (p. 19). Failure to comply with correct glove protocol was also reported by Casanova, Rutala, Weber, & Sobsey (2012), who studied the effect of double-gloving versus single-gloving in health care workers' transfer of virus.

A U.S. national study of the use of personal protective equipment among paramedics found that "...lack of access to safety devices is the major barrier to their use" (Mathews, Leiss, Lyden, Souse, Ratcliffe, & Jagger, 2008, p. 749). Lack of compliance with personal protective equipment was cited as a risk factor for clinical laboratory acquired *Brucella* infection among healthcare workers in Turkey; that study also found that people who had worked longer in clinical laboratories were less likely to acquire brucellosis (Sayin-Kutlu, Kutlu, Ergonul, Akalin, Guven, Demiroglu, Aiicbe, & Akova, 2012). Neves, Souza, Medeiros, Munari, Ribeiro, & Tipple (2011) conducted a qualitative study using the Health Belief Model to examine nurses' compliance with the use of personal protective equipment, and found "Adherence to personal protective equipment is determined by the context experienced in the workplace, as well as individual values and beliefs, but the decision to use personal protective equipment is individual" (p. 360). This suggests that individuals' values and beliefs may be a target for intervention to improve compliance.

## Cost of Adverse Incidents in the U.S.

In 2007, there were $55.4 billion in total costs for injured workers in the United States, of which $27.2 billion were for medical costs (Leigh and Marion, 2012). However, there is no mechanism for tracking how many of these incidents occurred in laboratories, since there is no reporting mandate for laboratory accidents. In fact, "...no one keeps comprehensive national statistics on laboratory safety incidents" (Benderly, 2009).

The Environmental Protection Agency reports that there were 32,629 reportable chemical releases in the U.S. in the year 2011 (National Response Center, 2012). Chemical releases can affect food, water, air, soil, and consumer products (World Health Organization, 2009).

One study estimated the costs of biological agent release, and estimated that for each 100,000 people exposed to a biological agent, the cost would range from $477.7 million to $26.2 billion, including only costs for the healthcare system and economic losses due to premature death (Kauffmann and Meltzer 1997).

In terms of nuclear release, the world has recent experience with three major disasters: Three Mile Island in 1979, Chernobyl in 1986 and Fukushima in 2011. Cleanup costs include medical costs, resettlement of affected populations, environmental decontamination, and sealing the reactors. The costs for Three Mile Island were estimated at about $1 billion; for Chernobyl, $235 billion, and for Fukushima $200 billion (Pineda, 2011).

**History and Teaching of Laboratory Safety**

One of the first references to laboratory safety in professional journals was a paper written by Edward Kellar, published in 1910, entitled "Hygiene of the Small Chemical Laboratory" (Kellar, 1910). In this paper, Kellar recommended the use of natural ventilation to disperse fumes and vapors from chemical reactions. Another early paper discussing laboratory safety appeared in 1934 (Walker, 1934). This paper was primarily aimed at industry; it brought forth the idea that safety was not only of concern to laboratory personnel, but should also be of concern to employers, since unintentional reactions might result in capital losses to a company. An early reference to academic laboratory safety was a paper published in 1925 by a faculty member of Brown University which addressed proper chemical storage (Davison, 1925).

In 1964, the Journal of Chemical Education began publication of a series of articles dedicated to the topic of laboratory safety. The series continued until 1978, and was very popular; in fact, the series was collected and published in four volumes from 1967 to 1978 (Steer, 1967, 1971, 1974; Renfrew, 1978).

The American Chemical Society (ACS) has been one of the leading organizations to publish works which address teaching laboratory safety. ACS first published the book *Safety in Academic Chemistry Laboratories* in 1972, and at present they have published the seventh edition of this book (American Chemical Society, 2003). In 1978 ACS established its Division of Chemical Health and Safety, which began publication of the *Journal of Chemical Health and Safety* in 2006 (Hill, 2003). The National Research Council published the first edition of the very popular book

*Prudent Practices for Handling Hazardous Chemicals in Laboratories* in 1981, and recently published an updated edition (NRC, 1981, 2011).

A number of universities have chosen to develop one-hour courses devoted to laboratory safety (Lowry, 1978; Simpson, 1987; Miller & Richmond, 1998; Nicholls, 1982). One of the first was incorporated into the curriculum at Western Michigan University, and described by its author in a paper in the Journal of Chemical Education in 1978 (Lowry, 1978). He reported "It was necessary to develop this course 'from scratch', as no textbooks or outlines were found that would be suitable at the desired level" (p. A235). This course covered topics such as a review of thermochemistry and gas laws, toxic and respiratory hazards, fire and flammability, storage and handling of chemicals, and protective equipment (p. A237).

Simpson described two courses which addressed laboratory safety at the Northern Alberta Institute of Technology in 1987 (Simpson, 1987). The first course was designed to be presented in the first semester of a curriculum for training chemical technicians, and it included the topics of corrosives, flammable solvents, toxicity, reactives, and personal protective equipment (p. A6). By the fourth semester, the students were nearing the completion of their degrees and took the second course devoted to more advanced topics, including accident investigation, radioactives, risk analysis, and chronic toxins (p. A6).

A similar program at the University of Illinois at Chicago was discussed in 1982 (Nicholls, 1982). She described applying the "...principals of equilibrium, kinetics, free energy concentration, and gas laws to real situations" (p. A301). The topics covered in this course included toxicology, personal protective equipment, corrosives, flammables, explosives, ventilation and monitoring (p. A302).

Other than specific courses for laboratory safety, a number of publications describe other methods for delivering information and training about the hazards of laboratories (Matson, Fitzgerald & Lin, 2007; Helser, 1999; Gublo, 2003; DiRaddo, 2006; Alaimo, Langenhan & Tanner, 2010).

Matson et al. (2007) published a paper describing a video for laboratory safety that they produced for the U.S. Naval Academy. The video they produced was tailored to address the particular safety issues at the Naval Academy, and interspersed short 5- to 10-second clips from popular videos and movies with applicable safety instruction subtitled below the clip and more specific instructions following each clip (p. 1727). When compared with the standard safety video they had used in the past, their new tailored video resulted in no difference in score of a quiz given after each of the videos, but the newer tailored video was ranked more interesting (p. 1728).

Helser (1999) discussed the development of a safety scavenger hunt game at the State University of New York College at Oneonta. He assigned students to work in pairs during the first lab session and had them locate twenty-five safety-related objects in the lab from a list he furnished, and asked them to draw the locations on a map of the lab (p. 68). Along with discussion of standard safety rules, he developed this exercise as a "...cooperative, active project" (p. 68) to engage his students.

Also from the State University of New York, at Oswego, came a description of a laboratory safety trivia game (Gublo, 2003). She divided her students into teams of four people, and designed a game similar to the television show *Jeopardy!*™ in which one of several categories of questions is chosen, and within the category are questions of increasing difficulty awarded by increasing points (p. 425). She reports that the exercise provided an opportunity for interaction, and involved discussion of other safety questions and concerns (p. 425).

At Ferris State University in Michigan, DiRaddo (2006) informed readers about a program which critiques laboratory safety images presented in comics. He chose three images from popular comic books which portrayed characters working in laboratories, and contrasts them to real-life modern laboratory scenarios and practices (p. 572).

Seattle University at present uses a year-long safety team program in the undergraduate organic chemistry course (Alaimo et al., 2010). During regularly-scheduled laboratory experiments, a team of two or three students within the lab section are assigned as the safety team, and conduct a prelab safety presentation, monitor activities in the lab, and conduct a postlab inspection; each student serves on a safety team once each semester (p. 856). As part of this program, the authors administered a survey to assess self-reported behavior and knowledge to both groups involved in the safety-team program and to control groups which did not participate in the safety team; they found a significant difference among the responses to two of the twenty survey items, indicating that the safety team participants had increased knowledge of the location of waste material disposal, and more strongly agreed with the statement that lab coats should always be worn during labs (p. 859).

Many universities rely on a standard one- or two-hour basic laboratory safety course presented annually to employees - faculty, staff, undergraduate and graduate students who work for the university - because such training is mandated by regulatory authorities (Klane, 2004). This is the type of program that I designed and conduct at SIUC. Our one-hour basic lab safety training session is presented using PowerPoint™ and lecture. Topics discussed each year include the OSHA regulations involving laboratory work; description of common physical hazards found in laboratories (compressed gases, oxidizers, peroxidizable compounds, flammable liquids, reactive chemicals), common health hazards of laboratory work (carcinogens, corrosives, reproductive hazards, sensitizers), an overview of safety chemical handling and storage, recommendations for common safe laboratory practices (no eating, drinking, smoking; no mouth pipetting; work in fume hoods; work on semi-microscale) and a discussion of appropriate use of personal protective equipment, including wearing lab coats, eye protection, and proper glove protocol.

## Regulation of Laboratory Safety

The Occupational Safety and Health Administration, or OSHA, was created in 1970 as a Federal agency whose charge was to protect American workers from job-related illnesses, injuries and death (MacLaury, 1984). OSHA has two broad regulations to protect workers from chemical exposure: the Hazard Communication Standard, and Occupational Exposure to Hazardous Chemicals in Laboratories.

The Hazard Communication Standard, 29 CFR 1910.1200, was established in 1983 for chemical manufacturers, and the regulation was expanded to apply to all industries in the United States in 1987 (OSHA, 2006). This regulation included requirements that chemical manufacturers assess the hazards of the chemicals they produce or import, and communicate those hazards to the users through chemical labeling and safety data sheets; it also required that employers provide training to employees regarding the hazards of the chemicals with which they work.

The Hazard Communication Standard was designed for industrial workplaces, and some of the requirements were difficult to fulfill in laboratory settings, which pose very different exposure hazards; consequently, a new regulation called Occupational Exposure to Hazardous Chemicals in Laboratories was enacted in 1990 (NRC, 1995). This regulation is commonly referred to as the Lab Standard. The Hazard Communication Standard continues to apply in workplaces that are not defined as laboratories, while the Lab Standard takes precedence in laboratory settings.

One important requirement of the Hazard Communication Standard was the mandate for material safety data sheets, or MSDS, from chemical manufacturers (OSHA, 2006). MSDS list information including the manufacturer's name and address; the name of the product or compound; storage requirements; incompatibilities; fire dangers; and physical properties of the substance (NRC, 1995). Another important requirement was the mandate for improved chemical labeling; after the Hazard Communication Standard became law, chemical labels were required to include information about toxicity, reactivity, flammability, routes of exposure, storage requirements, and the use of personal protective equipment (Furr, 1990). Determining the hazards of a chemical when the lab worker is unfamiliar with it is now as easy as reading the chemical label (NRC, 1995). The Hazard Communication Standard was recently updated to become compliant with the Globally Harmonized System of the U.N. (OSHA, 2010). A more rigorous format for Safety Data Sheets (SDS, no longer MSDS) is required, and a more coherent system of warning words and symbols has been adopted (OSHA, 2010).

The Hazard Communication Standard has been called a prescriptive standard, which has strict mandates, while the Lab Standard has been described as a performance standard; that is, one for which the regulatory agency describes desired outcomes, while allowing flexibility in design of the methods used to reach the outcomes (NRC, 1995). The Lab Standard is a relatively short standard, encompassing only three pages, half of which are definitions, with a non-mandatory Appendix A that lists recommendations for good chemical hygiene practices (OSHA, 1990). This standard requires employers to determine exposure levels for employees; requires a chemical hygiene plan with some specific elements; requires employee training; and lists special requirements for work with particularly hazardous substances such as carcinogens, reproductive toxins, and substances with a high degree of acute toxicity (OSHA, 1990). Appendix A is not mandatory, but is a list of good chemical hygiene practices as recommended by the National Research Council's 1981 edition of *Prudent Practices*. Appendix A discusses general principles of lab safety; responsibilities of officials; laboratory design, maintenance and ventilation; components of the chemical hygiene plan; general procedures for working with chemicals; and safety recommendations (OSHA, 1990). As required by the OSHA Lab Standard, SIUC has a Chemical Hygiene Plan, or CHP, which can be accessed online (SIU, 2010). The CHP discusses a number of standard operating procedures for laboratories, including requirements for wearing lab coats and eye protection, general safety practices, use of ventilation hoods, chemical spills, and employee information and training. The CHP is enforceable by OSHA; failure to comply with the CHP can result in a violation notice, and was one of the primary charges against UCLA following the death of their researcher in 2008 (Christensen, 2011).

The use of personal protective equipment is such an important issue that OSHA has a separate regulation for this topic, and it was one of the earliest regulations passed into law (OSHA, 1974). The Personal Protective Equipment Standard is identified as Subpart I and has a number of significant sections such as Section 132, General Requirements for Personal Protective Equipment, Section 133, Eye and Face Protection, and Section 138, Hand Protection. Each of these sections requires that employers conduct risk assessments to determine the need for personal protective equipment, and that employers provide employees with appropriate personal protective equipment at no cost to the employee (NRC, 1995).

Other OSHA regulations apply to laboratory settings, in addition to the Lab Standard. These include the Respiratory Protection Standard, which addresses the use of masks and respirators; the Bloodborne Pathogens Standard, which is used to control the biologic hazards of human blood and blood-derived body fluids; and a number of standards found in 29 CFR 1910.1000, Toxic and Hazardous Substances (OSHA, 2006).

Common provisions of both the Hazard Communication Standard and the Lab Standard include the mandate that the employer provide training to employees regarding the hazards of the chemicals with which they work ; the requirement that employers monitor chemical exposure in some cases, and that they provide medical consultation to employees when exposure occurs; requirements for chemical labeling; and requirements for material safety data sheets (OSHA, 2010).

The Environmental Protection Agency regulates safe handling, storage and disposal of hazardous chemical waste through the Resource Conservation and Recovery Act, or RCRA, passed in 1976 (Campus Safety, Health and Environmental Management Association, 2002). Until this law was passed, disposal of hazardous chemical waste was largely unregulated, and it was common practice to dispose of hazardous chemical waste in uncontrolled landfills, which had the result of toxic chemicals leaching into and contaminating groundwater (U.S. EPA, 2012). RCRA includes requirements mandating training of people who generate or handle hazardous waste, including laboratory personnel, to enable them to recognize and safety handle hazardous chemical waste (Campus Safety, Health and Environmental Management Association, 2002).

## Theoretical Model

According to Kerlinger (1986), a theory is "...a set of interrelated constructs, definitions and propositions that presents a systematic view of phenomena by specifying relationships among the variables, with the purpose of explaining and predicting phenomena" (p.9).

There are a number of theories that have been used to explain and predict health behavior. They include theories of individual behavior, such as the Health Belief Model (Hochbaum, 1958), the Transtheoretical Model (Prochaska, 1984), and Stress and Coping (Lazarus & Folkman, 1984). Other theories address interpersonal, rather than individual, health behavior; included in this category are Social Cognitive Theory (Bandura, 1986); Social Networks and Social Support (Israel, 1982) and Patient-Provider Communication (Roter & Hall, 1991).

One of the most widely-used theoretical models for health behavior is the Theory of Reasoned Action (Fishbein & Ajzen, 1975), along with its extension, the Theory of Planned Behavior (Ajzen, 1985). The Theory of Reasoned Action, or TRA, was developed in an effort to provide a general theory that might be used to explain and predict behavior across a variety of disciplines (Fishbein & Ajzen, 2010).

The Theory of Reasoned Action proposes that someone's attitude toward a behavior, combined with subjective norms, will act to form a behavioral intent. Behavioral intentions are the "most important immediate antecedents of behavior" (Fishbein & Ajzen, 2010, p. 39).

Attitude and subjective norm are the two major constructs of this theory, and each of them is, in turn, formed by two other constructs. Attitude is a result of the combination of *behavioral beliefs* about outcomes of performing a behavior, and *evaluation* of the behavioral beliefs. Subjective norm is the product of *normative beliefs* – whether important referent people approve or disapprove of the behavior – and *motivation to comply* with the desires of the important referents.

Each of these constructs can be measured in specific ways (Ajzen & Fishbein, 1980). Behavioral beliefs about whether the performance of a particular behavior will result in a particular outcome are measured on a dichotomous or bipolar scale, using paired comparisons such as "agree-disagree" or "likely-unlikely". Evaluations are measured usually as "good-bad". Typically, a seven-point scale is used for these comparisons, ranging from a score of -3 to a score of +3. The score for behavioral belief is multiplied by the score for evaluation, which results in a total score for attitude (Ajzen & Fishbein, 1980; Ajzen, 2012).

Similarly, normative beliefs (whether important referents approve or disapprove of a behavior) are usually measured on a seven-point scale, using paired phrases such as "should – should not" scored from -3 to +3. Motivation to comply is typically measured on a unipolar scale, with values ranging from 1 to 7, using some iteration of the phrase "...generally, I want to do what my (referent) thinks I should do." Subjective norm measurement is a result of multiplying the score for normative belief by the score for motivation to comply (Ajzen, 2012).

The scores for attitude and subjective norm can be analyzed with reference to behavioral intention using the statistical tools of correlation and analysis of variance. These statistical analyses can indicate which of the constructs are most strongly associated with intention and behavior. Knowledge of important constructs may be then used to develop a target for intervention (Ajzen & Fishbein, 1980; Ajzen, 1991, 2012).

In 1986, Ajzen extended the Theory of Reasoned Action by adding an additional construct: perceived behavioral control (Ajzen & Madden, 1986). The extended theory was called the Theory of Planned Behavior. This third construct reflects what some people refer to as self-efficacy; it refers to a person's ability to perform an intended behavior in terms of factors which may be outside her control. This construct, like the two constructs of attitude and subjective norm, can be measured with two subconstructs, control belief and power of control (Ajzen, 2012). Control beliefs reflect thoughts about the availability of resources to perform, or to block, the behavior. Power of control is a measurement of a person's thoughts about how important, and how much impact, the availability or lack of resources will have on the intended behavior. Both control beliefs and power of control are usually measured on a unipolar scale with values ranging from 1 to 7 (Francis et al., 2004).

Analysis of the data usually includes computing scores for the three direct measures of predictors – attitudes, subjective norms and perceived behavioral control – and computing scores for the indirect measures of predictors – behavioral beliefs and evaluations, which compose attitude; normative beliefs and motivation to comply, which compose subjective norms; and control beliefs and power of control, which compose perceived behavioral control. The direct measures are analyzed by multiple regression, with the behavioral intention score as the dependent variable, and the scores for the three direct measures as the predictor variables. The two scores for indirect measures of each predictor are multiplied to create a new weighted score for each direct predictor, then analyzed using multiple regression with the behavioral intention as the dependent variable and the weighted indirect scores as the predictor variables. In order to determine which belief has the most influence on intentions, the scores for behavioral intentions are converted into only two groups (such as yes-no), and a t-test is done (Francis, et al., 2004).

The Theory of Reasoned Action/Theory of Planned Behavior are some of the most widely used behavioral theories in scholarly research (Armitage & Conner, 2001). A search of peer-reviewed journals in August 2012 revealed more than 250 articles published in the first seven months of 2012 which utilized the Theory of Planned Behavior.

## Other Behavioral Models

In terms of teaching or assessing laboratory safety behavior, no studies could be found that utilized a behavioral model to explain or predict lab safety behavior. Two studies have been done involving chemical safety behavior in industry which utilized behavioral models.

Cox et al. (2003) used the mental models theory to investigate workers' beliefs about the use of perchloroethylene in the drycleaning industry, and the use of rosin-based solder flux in the electronic industry. Their research suggested that for industrial setting, simpler user-based information regarding chemical hazards would be more effective in communicating hazards than the use of material safety data sheets.

Maierhoffer, Griffin and Sheehan (2000) tested various value relationship theories when they studied protective glove use for chemical protection in the hairdressing industry. They found that managers' use of gloves was directly related to their employees' use of gloves for chemical protection

## Summary

This review of literature discussed some recent serious laboratory incidents which resulted in damage and death, and has raised awareness of the hazards present in academic research laboratories. Common hazards present in laboratories include health hazards, such as carcinogens, toxins and reproductive hazards; and physical hazards, including flammable liquids and gases, radiation, and compressed gases. Hazards of work with biological agents, recombinant DNA, and animals were described. Engineering controls to protect against lab hazards are things like ventilation devices and sharps containers. Administrative controls to reduce hazards are expressed through development of standard operating procedures and written plans such as a chemical hygiene plan. Personal protective equipment commonly used includes lab coats, eye protection, and gloves. A number of approaches toward teaching laboratory safety at different institutions are discussed, and the program at SIU is described. Laws governing protection of employees in labs include OSHA's Hazard Communication Standard, Laboratory Standard, and Personal Protective Equipment Standard, with requirements for providing safety information to employees through training and labeling of hazardous agents. Ajzen's Theory of Planned Behavior was described as the behavioral model for the study. Chapter 3 discusses methods for the study.

# CHAPTER 3

# METHODS

## Purpose of the Study

This study utilized the Theory of Planned Behavior (Ajzen, 1985) to investigate the relationship among attitude, subjective norms, perceived behavioral control, self-reported behavior, and behavioral intention in terms of use of personal protective equipment in laboratories, and to examine the relationship between attitude toward laboratory safety training and behavioral intention in terms personal protective equipment. This information may enable us to design more effective interventions to prevent unintentional injury in laboratories, to prevent unintentional chemical, biological and radiological agent release to the environment, and to improve laboratory safety training.

## Research Questions

The study sought to answer these questions:

1. Can the three constructs in the Theory of Planned Behavior – attitude, subjective norm and perceived behavioral control – be used to predict behavioral intentions with respect to use of personal protective equipment in laboratories?

2. What is the relationship between measures of attitude toward laboratory safety training, and behavioral intention in terms of use of personal protective equipment?

3. What is the relationship between attitude toward use of personal protective equipment, and attitude toward laboratory safety training?

4. What is the relationship among demographic variables, and the constructs of attitude, subjective norm, and perceived behavioral control, with respect to use of personal protective equipment?

5. Can the three constructs in the Theory of Planned Behavior – attitude, subjective norm and perceived behavioral control – be used to predict self-reported behavior with respect to use of personal protective equipment in laboratories?

## Research Design

The research design was a quantitative, cross-sectional descriptive study. Descriptive studies use observational design; that is, there are no manipulations of variables (Crosby, Di Clementi and Salazar, 2006). A cross-sectional study is fixed in time (Babbie,1992).

The study utilized a survey method; survey methods are commonly used to understand the thoughts, opinions, feelings and behaviors of a population (Crosby, Di Clementi and Salazar, 2006). Bachman and Schutt (2007) have said "Surveys are extremely versatile, efficient, and generalizable research instrument" (p.203).

A standard paper-and-pencil distribution of the survey was used; although this method is more time-consuming than an electronic distribution, it has the advantage of increased response rate; some response rates to electronic surveys have been reported as less than 0.1% (Crouch, Robinson and Pitts, 2010). Face-to-face interview surveys are more expensive and time-consuming, while telephone surveys are more likely to be subject to sampling bias, given different uses of cell phones and land lines by different socioeconomic groups and ethnicities (Stoop & Harrison, 2012). Other advantages to paper-and-pencil surveys include low cost, and the fact that respondents are given unlimited time to consider their responses (Henniger & Sung, 2012).

The theoretical model tested was the Theory of Planned Behavior (Ajzen, 1985). The model describes three major constructs: attitude, subjective norms, and perceived control. These three major constructs can be used to predict behavioral intention, which in turn can be used to predict behavior. Each of the three major constructs is made up of two subconstructs; one of the subconstructs relates to salient beliefs, and one to the strength of those beliefs (Ajzen, 2012). The major construct of attitude is made up of the two subconstructs behavioral belief and evaluation of outcomes. The major construct of subjective norm is made up of the two subconstucts normative belief and motivation to comply. The major construct of perceived control is made up of the two subconstructs control belief and perceived power. Each of the major constructs can be measured directly by survey items using bipolar adjectives, based on semantic differential (Osgood, Suci & Tannebaum, 1957). Additionally, each of the subconstructs can be measured, also using bipolar adjective items; this yields an indirect measurement of the associated major construct. The scores for behavioral belief and evaluation of outcome can be multiplied to yield an indirect measurement of attitude; the scores for normative belief and motivation to comply can be multiplied to yield an indirect measurement of subjective norm; the scores for control belief and perceived power can be multiplied to yield an indirect measurement of perceived control. The indirect measurements should correlate with the direct measurements; this is one of several ways to help insure validity (Ajzen, 2012).

Items for the survey relating to the direct measurement of attitude, subjective norm, and perceived control can be adapted from similar items used in surveys on other topics, according to the guidelines described by Ajzen (2012). However, in order to develop items to measure the subconstructs, an additional step is involved .The subconstructs are based on salient beliefs, and a researcher cannot simply assume what the relevant salient beliefs are (Ajzen & Fishbein, 1980; Ajzen, 1991, 2012). Instead, a researcher must conduct a pilot study with a population sample asking open-ended questions to elicit the relevant salient beliefs (Ajzen, 2012). Information from these open-ended questions can then be used to develop bipolar adjective items to measure the subconstructs. The items must be in pairs: one item measures the salient belief, and the other item measures the strength of that belief (Ajzen, 1991, 2012).

## Study Population

The study population included people who had attended laboratory safety training at SIU between 2010 and 2012 and who were still associated with the University as faculty, staff or student at the time of the study. All employees of the University who work in a laboratory, or who work in an area which generates hazardous waste, are required to attend annual laboratory safety training. I design and conduct this training, which lasts approximately an hour, and is delivered in person using lecture and Power Point™. Attendance sheets are filled out by training participants, listing the last four digits of their Dawgtag or social security number, their first and last names, their employment status (faculty, staff, graduate student, undergraduate student), their department, building, lab number, and e-mail address. Attendance sheets for the years 2010, 2011, and 2012 were entered into a Microsoft Excel™ spreadsheet, with one page for each department or unit. The data in each page were then sorted alphabetically by employment status of faculty, staff, graduate student or undergraduate student, and multiple entries (repeat attendees) were eliminated. I conducted a search in the SIUC directory to determine which people were still associated with the University, and eliminated those who have left. The final population of the study consisted of 936 people.

## Pilot Study Instrumentation

A pilot study was conducted which included four demographic descriptor items; age, gender, number of training sessions attended, and employment status – that is, whether the respondent was a faculty member, staff member, undergraduate student or graduate student. Four items were included that directly measured attitude toward personal protective equipment: (8) wearing a lab coat is: worthless / valuable; (22) using gloves when handling chemicals is: inconvenient / convenient; (11) wearing closed-toe shoes in labs is: harmful / beneficial; (13) wearing eye protection in labs is: unnecessary / necessary. Three items were included that directly measured subjective norm for personal protective equipment: (12) my lab supervisor thinks I should wear eye protection in the lab: never / always; (20) my lab co-workers wear a lab coat in the lab: never / always; (26) my lab supervisor wears closed-toe shoes in labs: never / always. Three items were included that directly measure perceived control for personal protective equipment: (5) for me to wear eye protection in the lab is: impossible / possible; (14) if I needed to, I could use a fire extinguisher in the lab: definitely false / definitely true; (15) it's mostly up to me whether I use gloves in the lab: strongly disagree / strongly agree. Three items were used to measure behavioral intent for personal protective equipment: (19) in the next month, I plan to wear eye protection in the lab: never / always; (24) in the next month, I'm going to try to wear a lab coat in the lab: never / always; (6) in the next month, I'm going to use gloves when I handle chemicals: never / always. The same three items were changed to read "in the past month, I have...never / always" to measure self-reported behavior for personal protective equipment; those items are (16), (21), and (25). To measure attitude toward lab safety training, three items were used: (23) lab safety training is: boring / interesting; (17) lab safety training is worthless / valuable; (7) lab safety training gives me useful information: never / always.

Also in the pilot study, six open-ended questions were included to elicit salient beliefs for the subconstructs of behavioral beliefs, normative beliefs, and control beliefs. These items were presented in pairs, in accordance with Ajzen (2012). To elicit behavioral beliefs, the questions were: (18) what are some of the benefits of using personal protective equipment? What are some of the costs (time, money, other costs) of using personal protective equipment? To elicit normative beliefs, the two open-ended questions were: (10) who are some of the people who might approve of you using personal protective equipment? Who are some of the people who might disapprove? To elicit control beliefs, the two questions were: (27) what are some things that might make it easy to use personal protective equipment? What are some of the things that might make it difficult?

All the items were numbered sequentially, and a random-number generator was used to order the items in the pilot survey. The three pairs of open-ended questions were treated as one item and kept together.

**Pilot Study Readability Grade and Institutional Review Board**

Prior to administration of the pilot test, readability grade level was conducted using the readability tool in Microsoft Word™, which is based on the Flesch-Kincaid Readability Test (Kincaid, Brady & Wulfeck, 1983). Target readability range was grade 7.0 to grade 8.0 (Kincaid et al., 1983) and, following adjustments, the pilot test readability was rated at grade 7.8, within the target range.

Approval of the SIUC Institutional Review Board (IRB) to conduct the pilot test was received, and is included as Appendix A; the pilot test instrument is included as Appendix B. The pilot test was distributed to a random sample of 2 faculty members, 7 staff members, 13 graduate students and 3 undergraduate students. This sample was selected from the study population by a random number generator. The pilot survey was a paper-and-pencil survey; the packet included the cover letter required by the IRB, which is included as Appendix C; the survey instrument, a return envelope, and a pencil to complete the survey. The pilot surveys were personally delivered in an envelope for Campus mail; pilot surveys were returned through Campus mail at SIUC. All of the pilot studies distributed were completed and returned.

## Pilot Survey Analysis

Each of the items, other than the demographic items and open-ended items, was scored on a scale of 1 to 7, with lower scores indicating less favorable response. None of the items in the pilot study was reverse-coded. Responses were entered into an Excel™ spreadsheet, and scores were generated for the constructs of attitude, subjective norm, perceived control, behavioral intention, and self-reported behavior for personal protective equipment, and for attitude toward safety training. To insure temporal stability and accuracy, ten of the responses were re-coded three days after the first code entry and compared for consistency; there were no errors in initial coding.

Data were analyzed using Statistical Package for the Social Sciences™, or SPSS™, version 20. When data entry was complete, the scores for items 8, 22, 11, and 13 were added and a mean determined to generate a score for attitude. The scores for items 12, 20, and 26 were added and a mean determined to generate a score for subjective norm. The scores for items 5, 14, and 15 were added and a mean determined to generate a score for behavioral control. The scores for items 6, 19, and 24 were added and a mean determined to generate a score for behavioral intention. The scores for items 7, 17, and 23 were added and a mean determined to generate a score for attitude toward training. The scores for items 16, 21, and 25 were added and a mean determined to generate a score for self-reported behavior. Frequencies and percentages were determined for the four demographic variables.

The items included in the pilot study, and the appropriate analysis performed, are summarized below in Table 1.

Table 1.

*Pilot Study Research Questions, Survey Items and Analyses Summary*

| Research Question | Pilot Survey Items | | Analysis |
|---|---|---|---|
| | Independent Variables | Dependent Variable | |
| 1.Which construct best accounts for the variability in the population regarding behavioral intentions? | Attitude: 8, 22, 11, 13<br>Subjective Norm: 12, 20, 26<br>Behavioral Control: 5, 14, 15 | Behavioral Intention: 19, 6, 24 | Multiple regression |
| 2.What is the relationship between training attitude and behavioral intention? | Training attitude: 23, 17, 7<br>Behavioral Intention: 19, 6, 24 | | Correlation |
| 3.What is the relationship between PPE attitude and training attitude? | PPE attitude: 8, 22, 11, 13<br>Training attitude: 23, 17, 7 | | Correlation |
| 4.What is the relationship between the demographic variables and safety attitude, subjective norm and behavioral control? | Age: 1<br>Gender: 2<br>Employment Status: 3<br>Number of trainings attended: 4<br>PPE attitude: 8, 22, 11, 13<br>Subjective norm: 12, 20, 26<br>Behavioral control: 5, 14, 15 | | ANOVA |
| 5.What is the relationship between PPE attitude, subjective norm, behavioral control and past behavior? | Independent Variables:<br><br>PPE attitude:8, 22, 11, 13<br>Subjective norm: 12, 20, 26<br>Behavioral control: 19, 6, 24 | Dependent Variable:<br><br>Past behavior: 16, 21, 25 | Multiple regression |

To determine a level of significance, or α, it is necessary to consider the consequences of making a Type I error (rejecting a true null hypothesis) (Hinkle et al., 1998). The most frequently used α levels are $p<0.01$ and $p<0.05$. Since the consequences of making a Type I error in this study are not severe, I chose to use the level of significance of $p<0.05$. That is, I felt that an acceptable risk of making a Type I error was 5%.

To answer the first research question, multiple regression was performed with the variables PPE attitude, subjective norm, and behavioral control as the independent variables, and with behavioral intention as the dependent variable. Results indicated that 62.5% of the population variability was explained by the model, and that both attitude and subjective norm were statistically significant ($p=0.029$ and 0.001 respectively), while behavioral control was not significant ($p=0.181$).

To answer the second research question, correlation was performed with the variables training attitude and behavioral intention. Pearson's correlation coefficient was 0.647, significant at $p=0.001$ (2-tailed).

To answer the third research question, correlation was performed between the variables of PPE attitude and training attitude. Pearson's correlation coefficient was 0.548, significant at $p= 0.005$ (2-tailed).

To answer the fourth research question, analysis of variance was performed for each of the demographic variables (age range, gender, employment status, number of trainings attended) with each of the variables of attitude, subjective norm, and behavioral control. Since the demographic variables are categorical data, ANOVA is the appropriate analysis (Hinckle, Wiersma & Jurs, 1998). There were no significant results found from the analysis of variance.

To answer the fifth research question, multiple regression was performed with the variables PPE attitude, subjective norm, and behavioral control as the independent variables, and with past behavior as the dependent variable. The results indicated that the model explained 60% of the population variability, with subjective norm the only construct that was statistically significant ($p=0.001$), while attitude $p=0.135$ and behavioral control $p=0.126$.

## Pilot Study Reliability and Validity

Reliability of the pilot survey items were established by analyzing for internal consistency using Cronbach's alpha, which is perhaps the most widely used indicator of internal consistency (Kimberlin & Winterstein, 2008). Cronbach's alpha was calculated for attitude, subjective norm, perceived control, behavioral intention, and past behavior for personal protective equipment, and for attitude toward lab safety training. A desirable result for Cronbach's alpha is value greater than 0.60 (Kimberlin & Winterstein, 2008). Each of the constructs yielded an acceptable Cronbach's alpha value; the range was 0.62 to 0.90. Validity was established by extensive literature review of other studies utilizing the theory, careful operational definitions of the constructs, and expert review of the items used in the survey (Kimberlin & Winterstein, 2008). After examination of reliability and validity, all the items from the pilot study were included in the final study.

The open-ended questions from the pilot study were examined to generate salient behavioral beliefs, normative beliefs, and control beliefs. The responses to the open-ended questions are included as Appendix D. From that information, nine sets of items were developed. The first set of three items measure behavioral beliefs and evaluation of outcome; the scores from these paired items were multiplied to generate an indirect measure of attitude. The second set of three items measure normative beliefs and motivation to comply; the scores from these paired items were multiplied to generate an indirect measure of subjective norm. The third set of three items measure control beliefs and perceived power; the scores from these paired items were multiplied to generate an indirect measure of perceived control. For example, one item for behavioral belief was 30, "Wearing a lab coat helps protect me from chemicals (strongly disagree / strongly agree)" and its paired item for evaluation of outcome was 32, "I want to protect myself against chemicals (strongly disagree / strongly agree)." The nine paired items were included in the final study instrument.

## Final Study Instrument

Prior to administration of the final study, the instrument was reviewed by an expert panel. Panel members were selected based on the recommendations of the committee. Copies of the instrument were sent to Dr. Mark Kittleson, Professor and Head of the Department of Public Health Sciences at New Mexico State University, to Dr. Kathleen Welshimer, Associate Professor of Health Education at Southern Illinois University Carbondale, and to Dr. Kathleen Phillips, Professor of Health Studies at Eastern Illinois University . Copies of the instrument were also distributed to committee members. The items were listed grouped by construct; a check box recommending "Keep Item" or "Eliminate Item" followed, and a column for "Comments / Suggestions for Revision" was added next to each item. The cover letter requesting expert review and the review form are included as Appendix E. None of the items were eliminated, based on the expert panel recommendations. Two of the items were corrected for spelling errors.

The final study instrument included a total of 49 items. The four demographic items (1, 2, 3, and 4) were the first items in the study. The remaining 45 items were listed in order, and a random number generator was used to determine their placement in the final study.

The final study instrument included four items which directly measured PPE attitude (7, 10, 34, and 42); three items directly measured subjective norm (17, 21, and 38); three items directly measure perceived control (9, 25, and 26); three items measured behavioral intention (11, 20, and 29); three items measured self-reported behavior (13, 23, and 39); four items measured attitude toward training (8, 18, 36, and 40); three items measured behavioral beliefs (6, 14, and 30); three items measured evaluation of outcome (19, 32, and 33); three items measure normative beliefs (12, 27, and 28); three items measured motivation to comply (5, 22, and 41); three items measured control beliefs (15, 24, and 35); and three items measured perceived power (16, 31, and 37). The final set of items described the respondent's experience with accidents and injuries in the lab (44 through 49). Research questions, applicable survey items, and appropriate analyses are listed below in Table 2.

Table 2.

*Final Study Research Questions, Survey Items and Analyses Summary*

| Research Question | Final Survey Items | | Analysis |
|---|---|---|---|
| | Independent Variables | Dependent Variable | |
| 1.Which construct best accounts for the variability in the population regarding behavioral intentions? | PPE Attitude: 7,10,34,42<br>Subjective Norm: 17,21,38<br>Behavioral Control: 9,25,26 | Behavioral Intention: 11,20,29 | Multiple regression |
| 2.What is the relationship between training attitude and behavioral intention? | Training attitude: 8,18,36,40<br>Behavioral Intention: 11,20,29 | | Correlation |
| 3.What is the relationship between PPE attitude and training attitude? | PPE attitude: 7,10,34,42<br>Training attitude: 8,18,36,40 | | Correlation |
| 4.What is the relationship between the demographic variables and PPE attitude, subjective norm and behavioral control? | Age: 1<br>Gender: 2<br>Employment Status: 3<br>Number of trainings attended: 4<br>PPE attitude: 7,10,34,42<br>Subjective norm: 17,21,38<br>Behavioral control: 9,25,26 | | ANOVA |
| 5.What is the relationship between PPE attitude, subjective norm, behavioral control and past behavior? | Independent Variables:<br><br>PPE attitude: 7,10,34,42<br>Subjective norm: 17,21,38<br>Behavioral control: 9,25,26 | Dependent Variable:<br><br>Past behavior: 13,23,39 | Multiple regression |

Table 2. (Continued)

*Final Study Research Questions, Survey Items and Analyses Summary*

| | | |
|---|---|---|
| To establish validity of the direct measures of attitude, subjective norm, and behavioral control, those scores were compared with the indirect measures of the same constructs | Direct measure of PPE attitude:7, 10, 34, 42<br>Indirect measure of PPE attitude: behavioral beliefs 6, 14, 30 multiplied by evaluation of outcome 19, 32, 33<br><br>Direct measure of subjective norm: 17, 21, 38<br>Indirect measure of subjective norm: normative beliefs 12, 27, 28 multiplied by motivation to comply 5, 22, 41<br><br>Direct measure of behavioral control: 9, 25, 26<br>Indirect measure of behavioral control: control beliefs 15, 24, 35 multiplied by perceived power 16, 31, 37 | Correlation |

## Final Study Readability and Institutional Review Board Permission

Using the same method as the pilot study, the final stud was analyzed for readability. Target readability range was grade 7.0 to grade 8.0 (Kincaid et al., 1983) and, following adjustments, the final study readability was rated at grade 7.9, within the target range. The final study instrument was submitted to the Institutional Review Board for approval; approval was granted, and the approval form is included as Appendix F.

## Final Study Distribution

The final printed survey was designed to be a booklet; four 81/2" by 11" pieces of paper were printed, stapled, and folded in half to yield an eight-page booklet, with no more than seven items on each page. The study packet included the cover letter required by IRB; the study booklet; a self-addressed return envelope; and a pen as a gift. The final study cover letter and instrument are included as Appendix G.

The final study was distributed to half of the study population, 468 people. I flipped a coin to determine whether to begin the distribution on the even- or odd-numbered person for each department. Seventeen studies were returned as undeliverable, resulting in 451 studies delivered to valid addresses. All the studies were sent by Campus Mail, and the studies were also returned through Campus Mail via the enclosed return envelope. In the four-week period following the survey distribution, 145 surveys were returned, resulting in a 32.4% return. Two surveys were rejected because the subjects failed to complete 95% of the items; the final sample was 143.

Sample size for multiple regression depends upon the number of independent variables, the desired effect size, the desired power size, and the acceptable alpha value, according to Soper (2013). For a desirable effect size of 0.15, a power of 0.8, and an alpha level of $p<0.05$, with three independent variables (attitude, subjective norm, and behavioral control), the minimum sample size is calculated at 76. Since the sample size for my study was 143, the results from multiple regression analysis should be generalizable.

## Summary

The study was a quantitative, cross-sectional descriptive study which used Ajzen's Theory of Planned Behavior (1991) to examine attitude, subjective norm, perceived control, behavioral intention, and self-reported behavior regarding personal protective equipment in laboratories at SIU, and to examine attitude toward laboratory safety training. A survey instrument was developed and pilot-tested on a sample of people who attended annual laboratory safety training at SIUC in 2010, 2011, or 2012. Six open-ended questions were included in the pilot survey to elicit information regarding behavioral beliefs, normative beliefs, and control beliefs. Information gathered from the open-ended items in the pilot survey was used to develop additional items in the final survey. These items indirectly measured the constructs of attitude, subjective norm and perceived control through the subconstructs of behavioral beliefs, evaluation of outcomes, normative beliefs, motivation to comply, control beliefs, and perceived power. Following permission from the IRB and review by an expert panel, the final survey was administered to half the study population; 143 complete surveys were returned and analyzed. Chapter 4 will describe the results of the final survey.

# CHAPTER 4

# RESULTS

## Purpose of the Study

This study utilized the Theory of Planned Behavior (Ajzen, 1985) to investigate the relationship among attitude, subjective norms, perceived behavioral control, self-reported behavior, and behavioral intention in terms of use of personal protective equipment in laboratories, and to examine the relationship between attitude toward laboratory safety training and behavioral intention in terms personal protective equipment. This information may enable us to design more effective interventions to prevent unintentional injury in laboratories, to prevent unintentional chemical, biological and radiological agent release to the environment, and to improve laboratory safety training.

## Research Questions

The study sought to answer these questions:

1. Can the three constructs in the Theory of Planned Behavior – attitude, subjective norm and perceived behavioral control – be used to predict behavioral intentions with respect to use of personal protective equipment in laboratories?

2. What is the relationship between measures of attitude toward laboratory safety training, and behavioral intention in terms of use of personal protective equipment?

3. What is the relationship between attitude toward use of personal protective equipment, and attitude toward laboratory safety training?

4. What is the relationship among demographic variables, and the constructs of attitude, subjective norm, and perceived behavioral control, with respect to use of personal protective equipment?

5. Can the three constructs in the Theory of Planned Behavior – attitude, subjective norm and perceived behavioral control – be used to predict self-reported behavior with respect to use of personal protective equipment in laboratories?

**Final Study Data Analysis**

As with the pilot survey, data from the final survey were entered into a Microsoft Excel™ spreadsheet. To insure stability, 10% of the responses were re-entered one week after initial entry and checked for agreement. No data entry errors were found.

The raw data from items 1, 2, 3, and 4 were entered as the demographic variables age range, gender, employment status, and number of training sessions attended, respectively. The raw data from items 7, 10, 34, and 42 were added, and a mean determined, to generate a score for the direct measurement of personal protective equipment (PPE) attitude. Raw data from items 17, 21, and 38 were added, and a mean determined, to generate a score for the direct measurement of subjective norm. Raw data from items 9, 25, and 26 were added, and a mean determined, to generate a score for the direct measurement of behavioral control. Raw data from items 8, 18, 36, and 40 were added, and a mean determined, to generate a score for training attitude. Raw data from items 13, 23, and 39 were added, and a mean determined, to generate a score for self-reported behavior. Raw data from items 11, 20, and 39 were added, and a mean determined, to generate a score for behavioral intention. The raw data from items 6, 14, and 30 (behavioral beliefs) were paired with the data from items 19, 32, and 33 (evaluation of outcome). The pairs were multiplied, added, and a mean determined to generate a score for the indirect measure of attitude. The raw data from items 12, 27, and 28 (normative beliefs) were paired with the raw data from items 5, 22 and 41 (motivation to comply). The pairs were multiplied, added, and a mean determined to generate a score for the indirect measure of subjective norm. The raw data from items 15, 24, and 35 (control beliefs) were paired with the raw data from items 16, 31, and 37 (perceived power). The pairs were multiplied, added, and a mean determined to generate a score for the indirect measure of behavioral control.

Data were analyzed using Statistical Package for the Social Sciences™, or SPSS™, version 20. Frequencies and percentages were calculated for demographic items. Correlation and multiple regression were used to examine the relationship between PPE attitude, subjective norm, and perceived control as the independent variables, and behavioral intention as the dependent variable. Correlation was used to examine the relationship between attitude toward safety training and behavioral intention, and also between attitude toward personal protective equipment and attitude toward safety training. Correlation was used to examine the relationship between the indirect measures and the direct measures for PPE attitude, subjective norm, and perceived control. Analysis of variance was used to examine the relationship between each of the demographic constructs (gender, age, employment status, and number of training sessions attended) and PPE attitude, subjective norm, perceived control, behavioral intention, self-reported behavior, the indirect measure of attitude, the indirect measure of subjective norm and the indirect measure of perceived control. Correlation and multiple regression were used to examine the relationship between PPE attitude, direct measure of subjective norm, and direct measure of perceived control as the independent variables, and self-reported behavior as the dependent variable.

## Final Study Reliability and Validity

Validity was established by extensive literature review of other studies utilizing the theory, careful operational definitions of the constructs, and expert panel review of the items used in the pilot survey (Kimberlin & Winterstein, 2008). Reliability of the final instrument items was established by analyzing the direct measures of PPE attitude, direct measure of subjective norm, direct measure of perceived control, behavioral intention, self-reported behavior, and attitude toward training for internal consistency using Cronbach's alpha, which is perhaps the most widely used indicator of internal consistency (Kimberlin & Winterstein, 2008). However, indirect measures from the final instrument were not subjected to internal consistency analysis, since different beliefs forming these indirect measures may be inconsistent with each other (Ajzen, 2012).

The resulting Cronbach's alpha scores for the variables in the final study were all above the acceptable 0.60 level, except for the variable perceived control, which was 0.48. This variable was made up of three separate items; I tested Cronbach's alpha again with item 9 removed and the other two remaining; with item 25 removed and the other two remaining; and with item 26 removed and the other two remaining. None of the removal resulted in a Cronbach score of the minimum of 0.60. The analysis was completed with all three items included in the variable.

## Results of the Final Survey Analysis

To answer the first research question, multiple regression was performed with the variables PPE attitude, subjective norm, and behavioral control as the independent variables, and with behavioral intention as the dependent variable. Results are shown below in Table 3, 4 and 5.

Table 3.

*Final Study Model Summary, Research Question 1*

| Model Summary | | | | |
|---|---|---|---|---|
| Model | R | $R^2$ | Adjusted $R^2$ | Std. Error of the Estimate |
| 1 | .755[a] | 0.569 | 0.56 | 0.86308 |
| [a] Predictors: (Constant), Behavioral Control, Attitude, Subjective Norm<br>Dependent variable: Behavioral Intention | | | | |

Table 4.

*Final Study ANOVA, Research Question 1*

| Model 1 | Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 131.960 | 3 | 43.987 | 59.050 | 0.001 |
| Residual | 99.817 | 140 | 0.745 | | |
| Total | 231.778 | 143 | | | |
| Dependent variable: Intention | | | | | |
| Predictors: (Constant), Behavioral Control, Attitude, Subjective Norm | | | | | |

Table 5.

*Final Study Coefficients, Research Question 1*

| Model | | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | t | Sig. |
| 1 | (Constant) | .552 | .609 | | .906 | .367 |
| | Attitude | .343 | .083 | .276 | 4.154 | .001 |
| | Subj. Norm | .653 | .076 | .581 | 8.640 | .001 |
| | Behav. Control | -.160 | .079 | -.117 | -2.035 | .044 |
| Dependent variable: Behavioral Intention | | | | | | |

With an adjusted $R^2$ value of 0.56, the model explained 56% of the variability in the population. Attitude and subjective norm were significant at p=0.001. Behavioral control was significant at p=0.044. Since the a priori α level was 0.05, these results validate the model; that is, attitude, subjective norm, and behavioral control can be used as predictors for the use of PPE.

To answer the second research question, correlation was performed with the variables training attitude and behavioral intention. Pearson's correlation coefficient was 0.233, significant at p=0.006 (2-tailed). A positive attitude toward safety training is associated with intention to use PPE.

To answer the third research question, correlation was performed between the variables of PPE attitude and training attitude. Pearson's correlation coefficient was 0.332, significant at p= .001 (2-tailed). Thus, a positive attitude toward the use of PPE is associated with a positive attitude toward safety training.

To answer the fourth research question, analysis of variance was performed for each of the demographic variables (age range, gender, employment status, number of trainings attended) with each of the variables of PPE attitude, subjective norm, and behavioral control. There were no significant findings; there does not appear to be any relationship between the demographic variables and the construct variables.

To answer the fifth research question, multiple regression was performed with the variables PPE attitude, subjective norm, and behavioral control as the independent variables, and with past behavior as the dependent variable. Results are shown below in Tables 6, 7, and 8.

Table 6.

*Final Study Model Summary, Research Question 5*

| Model Summary | | | | |
|---|---|---|---|---|
| Model | R | $R^2$ | Adjusted $R^2$ | Std. Error of the Estimate |
| 1 | .508[a] | 0.258 | 0.241 | 1.36914 |
| [a] Predictors: (Constant), behavioral control, attitude, subjective norm<br>Dependent Variable: Past Behavior | | | | |

Table 7.

*Final Study ANOVA, Research Question 5*

| Model 1 | Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 87.380 | 3 | 29.127 | 15.538 | 0.001 |
| Residual | 251.188 | 140 | 1.875 | | |
| Total | 338.568 | 143 | | | |
| Dependent variable: Past Behavior | | | | | |
| Predictors: (Constant), Behavioral Control, Attitude, Subjective Norm | | | | | |

Table 8.

*Final Study Coefficients, Research Question 5*

| Model | | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | t | Sig. |
| 1 | (Constant) | 1.506 | .966 | | 1.559 | .121 |
| | Attitude | .281 | .131 | .187 | 2.143 | .034 |
| | Subj. Norm | .523 | .120 | .385 | 4.362 | .001 |
| | Behav. Control | -.234 | .125 | -.142 | -1.877 | .063 |
| Dependent variable: Past Behavior | | | | | | |

From the table, analysis indicate that subjective norm was significant at p=0.001, while attitude was significant at p=0.034. Behavioral control was not significant at p<0.05, since p=0.063. The results of this study indicate that both subjective norm and attitude are related to self-reported behavior, but the construct of behavioral control is not.

The demographic items were analyzed for frequency and percentages. Results from analysis of item 1, age range, is shown below in Table 9; gender distribution is shown in Table 10; employment status distribution is shown in Table 11, and distribution of number of training sessions attended is shown in Table 12.

Table 9.

*Age Distribution, Final Survey*

| Age Range | Frequency | Percent | Cumulative Percent |
|---|---|---|---|
| Under 20 | 6 | 4.2% | 4.2% |
| 21 to 30 | 71 | 49.7% | 53.9% |
| 31 to 40 | 24 | 16.8% | 70.7% |
| 41 to 50 | 23 | 16.1% | 86.8% |
| 51 to 60 | 17 | 11.9% | 98.7% |
| Over 60 | 2 | 1.3% | 100% |

Table 10.

*Gender Distribution, Final Survey*

| Gender | Frequency | Percent | Cumulative Percent |
|---|---|---|---|
| Female | 66 | 46.2% | 46.2% |
| Male | 77 | 53.8% | 100.0% |

Table 11.

*Employment Status Distribution, Final Survey*

| Employment Status | Frequency | Percent | Cumulative Percent |
|---|---|---|---|
| Undergraduate Student | 25 | 17.5% | 17.5% |
| Graduate Student | 58 | 40.6% | 58.1% |
| Staff | 21 | 14.7% | 72.8% |
| Faculty | 39 | 27.2% | 100.0% |

Table 12.

*Training Sessions Distribution, Final Survey*

| Number of Trainings Attended | Frequency | Percent | Cumulative Percent |
|---|---|---|---|
| 1 | 21 | 14.7% | 14.7% |
| 2 | 28 | 19.6% | 34.3% |
| 3 | 30 | 21.0% | 55.3% |
| 4 or more | 64 | 44.7% | 100.0% |

The training attendance sheets, which I used to define the population, don't give information about age, gender, or number of training sessions attended. However, the attendance sheets do give information about employment status. Of the 936 people in the entire population, 27.9% were undergraduates, so my sample of 17.5% undergraduates was lower than the population percentage. In the population, 45.3% were graduate students, and my sample included 40.6% graduate students, fairly representative. The total population had 9.6% staff, while my study sample was 14.7% staff, a little higher than the population. Faculty included 17.2% of the entire population, and the sample in my study had 27.2% faculty, higher than the population. Undergraduates were underrepresented in the sample, while staff and faculty were overrepresented.

The final six items in the survey asked about the respondents' history of injuries, either observed or suffered, in the lab. Results of the injury analysis are shown below in Table 13.

Table 13.

*Injury Distribution, Final Survey*

| Item | Yes, N | Yes % | No, N | No % |
|---|---|---|---|---|
| 44: I have never been hurt in a lab. | 90 | 62.9% | 53 | 37.1% |
| 45: I have seen someone else get hurt in a lab, but just a minor injury like a cut or a burn that didn't require a doctor's visit. | 76 | 53.2% | 67 | 46.8% |
| 46: I have been hurt in a lab, but just a minor injury, like a cut or a burn, that didn't require a doctor's visit. | 49 | 34.3% | 94 | 65.7% |
| 47: I have breathed in chemical fumes in a lab that made me feel sick. | 26 | 18.2% | 117 | 81.8% |
| 48: I have seen someone else get hurt in a lab, and it was a major injury that required a doctor's visit. | 20 | 14.0% | 143 | 86.0% |
| 49: I have been hurt in a lab, and it was a major injury that required a doctor's visit. | 5 | 3.5% | 138 | 96.5% |

Respondents were asked to mark all of the applicable statements; the statements were not mutually exclusive. The majority of people, 62.9%, reported that they had never been hurt in a lab. Analysis of item 43, "My lab is a safe place to work never / always," 79% of respondents marked 6 or 7 (almost always, or always).

To verify that the direct measures of PPE attitude, subjective norm, and perceived control were comparable to the indirect measures, correlations were performed. The correlation between the direct measure of PPE attitude and the indirect measure of PPE attitude was .713, $p<.01$. The correlation between the direct measure of subjective norm and the indirect measure of subjective norm was .573, $p<.01$. The correlation between the direct measure of perceived control and the indirect measure of perceived control was -.076, and was not significant. The indirect measures for attitude and subjective norm were well correlated with the direct measures, and so validate the model.

## Summary

Chapter 4 described the purpose of the study and the research questions. 143 people returned completed survey instruments. The study results for research question 1 indicate that Theory of Planned Behavior constructs of attitude, subjective norm, and behavioral control can be used to explain 56% of the variability in the population, and that all three of the constructs were significant at $p<0.05$. Results for research question 2 indicate a significant positive correlation between attitude toward safety training and the behavioral intent to use PPE. Results for research question 3 indicate that there is a significant positive relationship between attitude toward use of PPE and attitude toward safety training. Results for research question 4 indicate that there is no significant relationship between any of the four demographic variables and the theoretical constructs of attitude, subjective norm, and perceived control, with one exception – there was a significant relationship between attitude and the number of training sessions attended. Results for the final research question indicate that the model accounts for 24% of the population variability when attitude, subjective norm, and behavioral control are used to predict behavior; attitude and subjective norm were significant at $p<0.05$, but behavioral control was not significant. Chapter 5 will discuss the findings of the study.

# CHAPTER 5

# DISCUSSION, CONCLUSIONS, RECOMMENDATIONS

## Purpose of the Study

This study utilized the Theory of Planned Behavior (Ajzen, 1985) to investigate the relationship among attitude, subjective norms, perceived behavioral control, self-reported behavior, and behavioral intention in terms of use of personal protective equipment in laboratories, and to examine the relationship between attitude toward laboratory safety training and behavioral intention in terms personal protective equipment. This information may enable us to design more effective interventions to prevent unintentional injury in laboratories, to prevent unintentional chemical, biological and radiological agent release to the environment, and to improve laboratory safety training.

## Summary of the Study

A non-experimental, cross-sectional design was utilized to examine the relevant constructs of the Theory of Planned Behavior with regards to the use of personal protective equipment and to lab safety training at SIU Carbondale. The study population consisted of 936 people who had attended at least one session of lab safety training between 2010 and 2012. A pilot survey was conducted with 25 people to test item validity and reliability, and to obtain information to design additional survey items to indirectly measure the theoretical constructs. 451 paper-and-pencil surveys were delivered to the sample using Campus mail; 143 valid surveys were returned, also by Campus mail, over the period of the following four weeks. Results were scored, entered into an Excel™ spreadsheet, and analyzed using SPSS™ Version 20. Results were used to answer the following research questions.

## Research Questions

The study sought to answer these questions:

1. Can the three constructs in the Theory of Planned Behavior – attitude, subjective norm and perceived behavioral control – be used to predict behavioral intentions with respect to use of personal protective equipment in laboratories?

2. What is the relationship between measures of attitude toward laboratory safety training, and behavioral intention in terms of use of personal protective equipment?

3. What is the relationship between attitude toward use of personal protective equipment, and attitude toward laboratory safety training?

4. What is the relationship among demographic variables, and the constructs of attitude, subjective norm, and perceived behavioral control, with respect to use of personal protective equipment?

5. Can the three constructs in the Theory of Planned Behavior – attitude, subjective norm and perceived behavioral control – be used to predict self-reported behavior with respect to use of personal protective equipment in laboratories?

**Discussion of Results of the Final Survey: Research Question 1**

Multiple regression indicated that with an adjusted $R^2$ value of .56, 56% of the variability in the population was accounted for by the model. This adjusted $R^2$ value compares favorably with other studies utilizing the Theory of Planned Behavior, such as those by Martin, Nelson, LaPlante, Usdan, Umstattd & Perko (2010), who reported that the Theory of Planned Behavior accounted for approximately 30% of the variability in the population studied for gambling behavior, and the study by Smith-McLallen & Fishbein (2008), who reported that the theory accounted for 40 to 55% of the variability in the population. A study about physical activity in African American women used the Theory of Planned Behavior, and their model accounted for 53.4% of variability in the population (Carter-Parker, Edwards & McCleary-Jones, 2012).

This study indicates that the Theory of Planned Behavior could be used to predict behavioral intention in terms of the use of PPE. The constructs of attitude and subjective norm were significant at .001, and behavioral control significance was .044. Subjective norm was the construct most highly correlated with behavioral intention for PPE. All of the constructs exhibited acceptable levels of significance, although behavioral control was less predictive than attitude or subjective norm. Interventions designed to improve attitude and subjective norm should improve the intention to use PPE, and might be more useful than an intervention designed to improve perceived behavioral control. The most important predictor of PPE behavioral intent was subjective norm. Subjective norm, or the behavioral expectations of supervisors and peers, strongly influence lab workers' intentions to use PPE.

### Discussion of Results of the Final Survey: Research Question 2

To answer the second research question, correlation was performed with the variables attitude toward safety training and PPE behavioral intention. Pearson's correlation coefficient was 0.233, significant at $p=0.006$ (2-tailed). This indicates that there is a relationship between positive attitude toward training, and positive PPE behavioral intention; that is, people who reported that lab safety training was more interesting, valuable, and important were more likely to report that they intend to use PPE in the labs. Improving lab safety training ought to result in more appropriate and frequent use of PPE in the labs.

### Discussion of Results of the Final Survey: Research Question 3

To answer the third research question, correlation was performed between the variables of PPE attitude and training attitude. Pearson's correlation coefficient was 0.332, significant at $p= 0.001$ (2-tailed). Thus, the study showed that people who had a more favorable attitude toward training also had a more favorable attitude toward the use of PPE. Combined with the results to research question 2, this reinforces the conclusion that improvement in training should result in improved attitude toward, and use of, personal protective equipment.

However, the issue of non-response bias might cause us to be a bit cautious about this conclusion. Non-response bias is always a concern with surveys; that is, it is possible that the people who responded to the survey were more interested and engaged in lab safety issues than the remainder of the population, and are not truly representative of the population. Shlomo, Skinner & Schouten (2012) tell us that response rate alone is not sufficient to insure against non-response bias. Some methods listed by MacDonald, Newburn-Cook, Schopflocher & Richter (2009) to improve response and to defend against non-response bias include using incentives, utilizing a shorter survey, and appearance of the survey. I used the incentive of including a free pen with the survey, limited the survey to fewer than 50 items, and designed the survey as a booklet, which should be more interesting and appealing to respondents.

## Discussion of Results of the Final Survey: Research Question 4

To answer the fourth research question, analysis of variance was performed for each of the demographic variables (age range, gender, employment status, number of trainings attended) with each of the variables of PPE attitude, subjective norm, and behavioral control. There were no significant relationships between age range, gender, or employment status and any of the three constructs of PPE attitude, subjective norm or behavioral control.

Ajzen (2012) refers to demographic factors as a kind of background factor, acting on the subconstructs of beliefs and thus mediating behavioral intention. The study showed that gender, age, and employment status are not significantly associated with attitude, subjective norm, or behavioral control, either positively or negatively. Thus, there is not a particular gender or age group that should be targeted for training improvements.

## Discussion of Results of the Final Study: Research Question 5

Multiple regression analysis showed an adjusted $R^2$ value of .241, indicating that only 24.1% of the population variability was accounted for by the model. Significance for subjective norm was the best of the three constructs, at $p<0.001$, with attitude significant at $p<0.034$ and behavioral control listing significance at $p<0.063$. It appears that the model is not an excellent predictor of self-reported behavior. This may be due, in part, to the low reliability score for the construct of behavioral control. It is not, however, unusual for one of the three constructs in the Theory of Planned Behavior to contribute only slightly, or not at all, to explain the variability in the population (Ajzen, 2012).

## Discussion of Other Analysis of the Data

The age distribution for the respondents was heavily weighted toward the age group 21 to 30, with almost 50% of respondents falling in this range. The next two age ranges, 31 to 40 and 41 to 50, each encompassed about 15% of the respondents. The two extreme age ranges accounted for the fewest number of respondents, as would be expected; people under age 20 represented 5.1%, while people over age 60 represented only 1.4%.

Undergraduate and graduate students in their 20s are actively engaged in learning laboratory techniques and habits that may be used for the rest of their professional careers. Instilling the appropriate use of PPE for this age group may help reduce unintentional injury over the course of many years, which could result in longer, more productive work lives.

When I examined the distribution of the number of training sessions attended, I found that 15.2% of respondents had attended one training session, 20.3% had attended two sessions, 19.6% had attended three sessions – but 44.9% of respondents had attended four or more training sessions. It's not possible to determine if that is representative of the population or not; training is required annually, but since I didn't ask how long the respondent had been associated with the University, I don't know how many sessions they should have attended. This figure does tell me that nearly half of the respondents had been associated with the University for at least four years. Again, the possibility of nonresponse bias arises, but efforts were taken to reduce that.

The number of undergraduate respondents (17.5%) was considerably lower than the study population (27.9%). This was probably due to a simple physical limitation: the surveys were delivered to the departmental offices using Campus mail, and undergraduate students do not typically have mailboxes in the departmental office. It may have been more difficult to find the undergraduate students and deliver the survey to them. When I could determine the specific lab in which the undergraduate students worked, I wrote that on the Campus mail envelope (i.e. "John Smith, c/o Dr. Jones'

Lab"). Seventeen of the original 486 surveys were returned as undeliverable, and all but one of those was addressed to an undergraduate student. These students were still listed as attending the University, but it may be that they no longer worked for that lab.

There was a positive relationship between the constructs behavioral intention and self-reported past behavior, with Pearson's R at 0.705, $p<0.01$, two-tailed. This seems to indicate that people did not intend to change their behavior much, when behavior during the past 30 days is compared to behavioral intention for the next 30 days. It appears that simply taking the survey didn't really act to change people's behavioral intentions drastically.

Items 43 ("My lab is a safe place to work never / always") and items 44 through 49 concerning injuries in the lab, were included to assess the relative frequency of injuries either observed or suffered by the respondents. These items were not included on the pilot survey. The data from these items on the final survey was analyzed using frequencies and percentages.

In reply to the item "My lab is a safe place to work never / always," 58.7% (N=81) responded "Strongly agree" to the statement, and an additional 21% (N=29) marked 6 on the 7-point scale; thus, almost 80% of respondents felt that their lab was usually or always a safe place to work. 63% (N=90) reported they had never been hurt in a lab. 53% (N=76) had seen someone else hurt in a lab, but only a minor injury, while 34% (N=49) had themselves been hurt in a lab, but only suffered a minor injury. A relatively small number (N=26, or 18%) of respondents reported that they had breathed in chemical fumes in a lab that had made them feel sick. Of the 26 people who reported breathing chemical fumes, 6 of them did not report ever being hurt in a lab accident, so they didn't consider breathing in chemical fumes as suffering from an accident. About 14% (N=20) reported that they had seen someone else hurt in a lab who suffered from a major injury that required a doctor's visit, while only 3.5% (N=5) reported that they had suffered a major injury in a lab that required a doctor's visit. These figures indicate that even though 39% of respondents had been hurt in a lab (42.5% when the additional people who breathed in fumes were added), almost 80% felt that their lab was usually or always a safe place to work.

One reason I conducted the study was the desire to improve the training program I present to lab workers. The mean score for attitude toward training was 6.00 (scale from 1 to 7), so study subjects seem to have a positive attitude toward training; however, the possibility of nonresponse bias should be considered, as discussed above.

Subjective norm was the construct which was most predictive of behavioral intention for personal protective equipment. Training could be improved by informing students, faculty and staff of this information, by emphasizing collegiality, and by encouraging people to remind labmates to use appropriate PPE. During the next training sessions I intend to ask lab supervisors to set the standard for PPE use in their labs, by always wearing a lab coat, eye protection, and gloves when they enter the lab, since this should reinforce expectations of use for their students and staff.

65 of the 143 respondents, or 46%, marked 4 or less on the response to question 37, "I don't know how to get my lab coat cleaned strongly disagree / strongly agree" (reverse coded), indicating that quite a number of people don't know that SIUC has a contract with a laundry service to clean lab coats for $0.85 each. I will add this

information to my training program, with the admonition that no one should take a lab coat home to wash it. 25 people (18% of respondents) marked 4 or less for item 15, "I have a lab coat to wear strongly disagree / strongly agree." When discussing the use of PPE in training, I'm going to add that the University, as an employer, is responsible for providing appropriate PPE to employees free of charge, including lab coats, and is also responsible for the cost of maintaining them (laundry and repairs).

The University is responsible for providing appropriate eye protection to employees, including proper-fitting eye protection. In response to item 35, "I have eye protection that fits me strongly disagree / strongly agree," 28 people (20%) marked 4 or less on the scale of 1 to 7. I will add information to the training program about the responsibility of the lab supervisor to make sure everyone has eye protection that fits. Only 9 people (6.5%) marked 4 or less in response to item 24, "There are gloves available in my lab strongly disagree / strongly agree," while 20 people (14%) marked 4 or less in response to item 16, "If I use too many gloves, my lab supervisor will be angry strongly disagree / strongly agree," (reverse coded). In 2012 I added the topic of glove protocol to my training, and I see from the study results that I need to clarify and emphasize the fact that gloves should always be removed when people leave the lab, even if it is just to walk down the hallway and get a sample from an ultralow freezer. When supervisors realize that requirement, they should be less likely to limit the number of gloves used.

However, 27 people (20%) marked 4 or less in response to item 28, "My lab supervisor doesn't care if I wear gloves or not strongly disagree / strongly agree," (reverse coded). This seems to indicate that about a fifth of lab workers may feel that their lab supervisor doesn't care about their safety, or perhaps that their lab supervisor expects them to be able to determine when glove use is appropriate. When considered with the criminal felony charges in the UCLA case (Lichterman, 2012) which fixed the responsibility for lab employee safety primarily on the principal investigator (rather than the institution), it is clear that during training I need to emphasize the responsibility of the principal investigator. I will also add information regarding the anticipated availability of the risk assessment tool authored by the ACS, and advise its use in all research laboratories.

## Conclusions

1. Of the three main constructs in the Theory of Planned Behavior, subjective norm is the best predictor of behavioral intention regarding the use of personal protective equipment. Observation of peer and supervisor use of personal protective equipment is a descriptive subjective norm which acts to influence lab workers' behavioral intentions.

2. Respondents who had a favorable attitude toward training and a favorable attitude toward the use of personal protective equipment were more likely to report favorable intentions to use PPE. Improvements in training should improve the use of PPE.

3. There does not appear to be a particular population, based on age or gender, which would be a target for intervention in terms of more training for the use of PPE. Subjective norm and attitude are predictive of behavioral intention for both genders and all age ranges.

4. About 80% of respondents felt that their lab was a safe place to work usually or always. However, 39% to 42% of the same respondents reported being hurt in a lab accident.

## Limitations of the Study

This study was a theory-based study of human behavior in scientific laboratories in higher education; I have been unable to find any similar studies to compare results, even in other scientific settings, such as industrial research and development laboratories, or government laboratories. Thus, researchers should be cautious about generalizing these results to other laboratory populations or work settings.

Institutions of higher education are only required to report injuries to OSHA from employees. Thus, there is no available national (or international) data regarding injuries in laboratories of students. This study found that 9 of the 25 undergraduate student respondents reported that they had been hurt in a lab, and 29 of the 55 graduate student respondents reported that they had been hurt in a lab, but there is no way to determine if those injuries occurred here at SIUC, or in a lab at another institution. Limited data availability makes it impossible to compare injury rates to other institutions.

Both the study population (N=936) and the sample size (N=138) were relatively small compared to many research institutions. Further research is necessary before reliably generalizing these findings to other institutions.

The use of lab coats, gloves, and eye protection is mandated at this institution, but the mandate is not enforced. People who work in labs may choose to wear PPE only when they believe it is necessary for the work they're performing. Therefore, a future researcher should consider re-wording some of the behavioral intention items to say "*When performing work that requires gloves,* in the next 30 days I am going to try to wear gloves never / always."

## Recommendations for Future Research

More research should be conducted to determine who is being injured in laboratories, and the nature of their injuries. This should act to improve training and reduce injuries. It's very difficult to estimate the extent of the problem with laboratory injuries unless we are able to obtain reliable data regarding frequency and severity.

This study did not find differences in attitude, subjective norm, behavioral control or behavioral intention between the genders, or among different age groups; however, the topic should be investigated with reference to nationality (or culture) and language. Scientific disciplines have a number of international students who may have different attitudes, norms and behavioral control than those of domestic students. These differences may impact the utility of training, and the motivation to wear PPE.

The construct of behavioral control was not predictive of behavioral intention for use of PPE; that is, both people who reported low and high scores for behavioral control were no more or less likely to report high scores for behavioral intention. Research should be conducted to investigate the possible confounding factors that make this construct less predictive than the others.

This study should be replicated in different work settings, such as an industrial research and development institution, or a government research institution, to determine if there are differences in the importance of the constructs among non-academic scientific personnel.

There may be a difference in attitude, subjective norm, or behavioral control when the size of the institution is considered; the study should be replicated at larger institutions. In addition, the constructs may differ in importance for labs which employ more people, or which utilize more highly-hazardous materials.

In labs where use of PPE is not mandated, but voluntary, the methods by which a worker decides to use PPE should be investigated. Are there formal risk assessments conducted, or informal individual risk assessments? Does the use of formal risk assessments have an effect on attitude, subjective norm, or behavioral control?

In the review of literature, the study described safety training program delivered on-line, training using videos or games to deliver content, and described institutions which offered a separate course for laboratory safety. Research should be conducted to determine if there are differences among PPE attitude, subjective norm, behavioral control, or training attitude when lab workers receive lab training through different methods. In addition social media, such as Facebook™, Twitter™, and Tumblr™ should be explored as new methods to deliver lab training.

## Recommendations for Health Education Practices

Health education practitioners should collaborate with scientists, and with the environmental health and safety community, to help develop theory-based training programs. Occupational health and safety training programs, like other health education programs, can be more effective if they are guided by theory, and if they have measurable goals and outcomes.

Health education practitioners should advocate for mandated collection of unintentional injury data for students in higher education. Lack of basic data concerning laboratory injuries and accidents makes it impossible to compare rates at different institutions, different laboratories, different disciplines, and makes it impossible to know if laboratory injuries are increasing or decreasing. The problems must first be defined before we can determine how to develop effective interventions.

There is a need for useful, readable literature for safety training in laboratories; health education professionals should assist in provision of such literature. Such literature should include the basics of program planning and evaluation, so that benchmarks can be established in terms of safety training and the use of PPE.

Health educators can assist scientific researchers in developing safety training materials that are appropriate for workers of many cultures, nationalities, and languages.

The current content for laboratory safety training at most institutions of higher education is controlled primarily by the requirements of regulations, such as those from OSHA and EPA (Fogarty & Shaw, 2010). Health educators should conduct true needs assessments, and formative program assessments, to determine if the current training topics actually reflect the needs of the lab workers, and in what areas the training programs could be strengthened.

Utilizing behavioral models like the Theory of Planned Behavior or the Health Belief Model (Hochbaum, 1958), health educators could help identify factors that might raise barriers to PPE implementation, and methods to reduce those barriers.

## Summary

This study examined attitudes, subjective norm, behavioral control, behavioral intention, and self-reported behavior in reference to the use of personal protective equipment in laboratories, and examined attitude in reference to laboratory safety training, using the Theory of Planned Behavior (Ajzen, 1985). Following a pilot test to elicit salient beliefs, 143 scientists at Southern Illinois University Carbondale responded to a questionnaire which included 49 items to test the constructs of the theory. The study showed that subjective norm is the construct which is most predictive of behavioral intention for the use of personal protective equipment (PPE), followed by attitude. Perceived control was not predictive of behavioral intention in this study. Direct and indirect measurements of the constructs were tested, and the results for attitude and subjective norm support the theoretical construct relationship. There was a significant positive relationship between PPE attitude and behavioral intention, and between training attitude and behavioral intention, indicating that improvements in training may result in improved attitudes toward training and PPE, and may improve behavioral intentions for PPE use. There is a great need for future research in this area.

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APPENDICES

# Pilot Study for Personal Protective Equipment and Safety Training

*This survey is anonymous, so please don't put your name or other identifying information on the form.*

This survey is about the personal protective equipment you might use in a lab, and about lab safety training.

When we say "your lab supervisor," we mean the person who tells you what to do when you work in a lab; that could be a professor, a postdoc, a staff member, or a grad student.

When we say "eye protection," we mean safety glasses, or safety goggles, or a face shield.

Please put a ✓ or a X on the line next to your group:

1. Your age range:

   ___ Under 20
   ___ 21 to 30
   ___ 31 to 40
   ___ 41 to 50
   ___ 51 to 60
   ___ Over 60

2. Your gender:

   ___ Female
   ___ Male

3. Your status at SIU:

   ___ Undergraduate student
   ___ Graduate student
   ___ Staff
   ___ Faculty

4. Number of lab safety training sessions you have attended while at SIU:

   ___ One
   ___ Two
   ___ Three
   ___ Four or more

Please put a ✓ or a X on the line that reflects your opinion:

5. For me to wear eye protection in the lab is:

Impossible ___ ___ ___ ___ ___ ___ ___ Possible

6. In the next month, I'm going to use gloves when I handle chemicals:

Never ___ ___ Sometimes ___ ___ Usually ___ ___ Always ___

7. Lab safety training gives me useful information:

Never ___ ___ Sometimes ___ ___ Usually ___ ___ Always ___

8. Wearing a lab coat is:

Worthless ___ ___ ___ ___ ___ ___ ___ Valuable

9. Lab safety training is:

Harmful ___ ___ ___ ___ ___ ___ ___ Beneficial

10. Who are some of the people who might approve of you using personal protective equipment?

_______________________________________________

_______________________________________________

Who are some of the people who might disapprove?

_______________________________________________

_______________________________________________

11. Wearing closed-toe shoes in the lab is:

Harmful ___ ___ ___ ___ ___ ___ ___ Beneficial

12. My lab supervisor thinks I should wear eye protection in the lab:

Never ___ ___ Sometimes ___ ___ Usually ___ ___ Always ___

13. Wearing eye protection in the lab is:

Unnecessary ___ ___ ___ ___ ___ ___ ___ Necessary

14. If I needed to, I could use a fire extinguisher in the lab:

Definitely False ___ ___ ___ ___ ___ ___ ___ Definitely True

15. It's mostly up to me whether I use gloves in the lab:

Strongly Disagree ___ ___ ___ ___ ___ ___ ___ Strongly Agree

16. In the past month, I've worn eye protection in the lab:

Never ___ ___ Sometimes ___ ___ Usually ___ ___ Always ___

17. Lab safety training is:

Worthless ___ ___ ___ ___ ___ ___ ___ Valuable

18. What are some of the benefits of using personal protective equipment?

________________________________________________________

________________________________________________________

What are some of the costs (time, money, other costs) of using personal protective equipment?

________________________________________________________

________________________________________________________

19. In the next month, I plan to wear eye protection in the lab:

Never ___ ___ Sometimes ___ ___ Usually ___ ___ Always

20. My lab co-workers wear a lab coat:

Never ___ ___ Sometimes ___ ___ Usually ___ ___ Always

21. In the past month, I've used gloves when I handle chemicals:

Never ___ ___ Sometimes ___ ___ Usually ___ ___ Always

22. Using gloves when handling chemicals is:

Inconvenient ___ ___ ___ ___ ___ ___ ___ Convenient

23. Lab safety training is:

Boring ___ ___ ___ ___ ___ ___ ___ Interesting

24. In the next month, I'm going to try to wear a lab coat in the lab:

Never ___ ___ Sometimes ___ ___ Usually ___ ___ Always

25. In the last month, I've worn a lab coat in the lab:

___ Never ___ ___ Sometimes ___ ___ Usually ___ ___ Always

26. My lab supervisor wears closed-toe shoes in the lab:

___ Never ___ ___ Sometimes ___ ___ Usually ___ ___ Always

27. What are some of the things that might make it easy for you to use personal protective equipment?

________________________________________

________________________________________

What are some of the things that might make it difficult?

________________________________________

________________________________________

My name is Ami Ruffing, and I am a graduate student in the Health Education program at Southern Illinois University Carbondale.

I am asking you to participate in my research study. The purpose of the study is to examine the use of personal protective equipment in labs, and ask about lab safety training. I hope to use the results of the study to help improve lab safety at SIU, and your participation is key to this effort.

You have been chosen to participate because you have attended a session of laboratory safety training at SIUC within the past three years. Participation in this study is voluntary.

If you choose to participate in the study by completing the questionnaire, it will take approximately twenty minutes of your time. The questionnaires contain no individual identification, so the survey is anonymous. Please don't put your name or other identifying information on the survey.

Completion and return of the survey will indicate your voluntary consent to participate in the study. I've included a return envelope for the completed surveys, and I've included a pen so you can fill the survey out. You may keep the pen when you're done as a thank-you.

If you have any questions about the study, please contact me, or my committee chair:

Ami Ruffing, M.S.
Center for Environmental Health and Safety
SIUC
Phone (618) 453-5187
aruffing@cehs.siu.edu

Dhitinut Ratnapradipa, PhD.
Department of Health Education
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Thank you very much for your participation.

This project has been reviewed and approved by the SIUC Human Subjects Committee. Questions concerning your rights as a participant in this research may be addressed to the Committee Chairperson, Office of Sponsored Projects Administration, Southern Illinois University, Carbondale, IL, 62901-4709. Phone (618) 453-4533. E-mail siuhsc@siu.edu

## Qualitative Responses for Pilot Study

Who are some of the people who might approve of you using personal protective equipment?

Boss
Lab manager
Professor/PI/Faculty
Labmates
Stockroom manager
Anyone who cares for my wellbeing
Everyone I know
OSHA
CEHS
My parents/family
People who are good to me
Administration
Glove manufacturers (ha ha)

Who might disapprove?

No one
Irresponsible and stupid people
My boss?
My enemies
Lucifer
Faculty
People who want me to die

What are some of the benefits of using personal protective equipment?

Safety
Safety from getting chemicals on skin, eyes, clothing
Cleanliness
Live longer.
Keep my face handsome
Added protection from chemical and biological hazards when engineering controls are not enough
Avoiding injuries
Protecting clothing
Prevent chemicals from being spread outside the lab
Safety, as well as preventing contamination of samples
Get away from spills, no direct contact with UV rays
Lessened risk of personal injury
Increased OSHA compliance
Protection against all the solvents I use every day
Not getting injured, burned, wounded

Following the rules, not getting fired!
You can protect yourself, and others around you

What are some of the costs?

It takes little time to put on lab coats, goggles, and gloves, so time is not an issue. Money is the most costly part of PPE. I use at least five pairs of gloves a day, but nitrile gloves are fairly cheap. I purchased my own lab coat ($20 – $30). Eyewear was purchased with grant funds, and are not expensive and last a long time.

Cost of gloves
Inconvenience / annoyance
Hot when I wear a lab coat
Money
Cost is worth it. Nothing is more important than health.
Discomfort, time
Increase mistake rate during experiments
I am not sure; maybe time.
For me directly, none.
Glasses don't usually fit well with eye protection
PPE is genuinely inconvenient to put on.

Time and money for gloves, especially since we have several labs, so need to remove them and put on new gloves when changing rooms (and it may happen quite often).

Gloves = $13/box, coat came from Goodwill ($4), time = a few seconds
There can be a cost if you use a special laundry service for your coats
Disposable gloves, and one-time costs for coats and eyewear
No cost is worth injury
Work takes longer

What are some of the things that might make it easy for you to use PPE?

A little reminder on how to use the equipment
Easy access to gloves and lab coats
Protective eyewear that is easy to use with glasses
Price, availability, convenience, awareness
Having lab coats, eyewear and gloves provided. Need respirators
Giving everyone their own lab coat, some people have to share
Lockers to store shoes/sandals
Safety glasses always available in every lab
Lab organization of PPE in one place
Contact lenses, to make eye protection more convenient
If the lab coats are cleaned by the school it would be helpful
Being available and easily obtainable
Knowledge of what type of PPE is best; ex. Nitrile glove
If the lab coat is clean

Having the right size. I wear XS gloves which most labs don't have. I bought my own lab coat because the ones provided were too big.

What are some of the things that might make it difficult?

Not having the proper instruction
Hot building (lab coat)
Not having eye protection to wear over glasses
We are spread out and moving from one room to another; it is inconvenient to glove/unglove/reglove
Being lazy
No access to lab coat
Bad regulation of heat/AC
Right-sized gloves are not always available
Not enough lab coats for everyone
Improper fit of PPE, obstructs movement and vision
If they are not supplied
Time
Not getting to wear what you want
Out of stock
Lack of funds
Supervisor NOT supporting of wearing PPE
PPE is not available in the lab
Lack of tactile sensitivity / visibility

Dear Dr. Kittleson,

As you know, I am a doctoral candidate in Health Education at Southern Illinois University Carbondale.

The members of my committee, Drs. Ratnapradipa, Ogletree, Ritzel, Wilken, and Reeve, have suggested that I have my survey instrument reviewed by experts. Would you be willing to review my instrument for content validity?

My dissertation is entitled "Personal Protective Equipment and Laboratory Safety Training: The Roles of Attitude, Subjective Norm and Perceived Control." The variables I will be investigating are attitude, subjective norm, perceived control, behavioral intention, and self-reported behavior with respect to the use of personal protective equipment in laboratories, and attitude toward safety training. The theoretical model I have chosen is Ajzen's Theory of Planned Behavior.

Two attachments are included with this message. The first is the instrument that will be administered to the subjects; the second is for your review of the instrument. For each item, please indicate on the second instrument if the item should be retained, deleted, or revised. If an item should be revised, I would appreciate your comments as to how it should be revised. Please return your completed review electronically to aruffing@cehs.siu.edu

Please contact me anytime if you have any questions or comments. If at all possible, I would appreciate it if you could return the instrument by January 10.

Thank you so much.

Sincerely,

Ami Ruffing

**Survey Items for Expert Review**

Personal Protective Equipment and Laboratory Safety Training: The Roles of Attitude, Subjective Norm and Perceived Control

N.B. There are also four demographic items on the survey: age, gender, employment status (undergrad, grad student, faculty, staff), number of training sessions attended at SIU.

Attitude

| Item # | Statement | Retain? | Delete? | Revise? Comments |
|---|---|---|---|---|
| 3 | Wearing a lab coat is worthless/valuable | | | |
| 30 | Using gloves in the lab is inconvenient/convenient | | | |
| 38 | Wearing closed-toe shoes in lab is harmful/beneficial | | | |
| 6 | Wearing eye protection in labs is unnecessary/necessary | | | |

Subjective Norm

| Item # | Statement | Retain? | Delete? | Revise? Comments |
|---|---|---|---|---|
| 34 | My lab supervisor thinks I should wear eye protection in the lab never/always | | | |
| 17 | My lab co-workers wear a lab coat in the lab never/always | | | |
| 13 | My lab supervisor wears closed-toe shoes never/always | | | |

Perceived Control

| Item # | Statement | Retain? | Delete? | Revise? Comments |
|---|---|---|---|---|
| 5 | For me to wear eye protection in the lab is impossible/possible | | | |
| 21 | If I needed to, I could use a fire extinguisher in the lab definitely false/definitely true | | | |
| 22 | It's mostly up to me whether I use gloves in the lab strongly disagree/strongly agree | | | |

Behavioral Intention

| Item # | Statement | Retain? | Delete? | Revise? Comments |
|---|---|---|---|---|
| 16 | In the next month, I plan to wear eye protection never/always | | | |
| 7 | In the next month, I'm going to use gloves when I handle chemicals never/always | | | |
| 25 | In the next month, I'm going to try to wear a lab coat in the lab never/always | | | |

Self-Reported Behavior

| Item # | Statement | Retain? | Delete? | Revise? Comments |
|---|---|---|---|---|
| 19 | In the past month, I've worn eye protection in the lab never/always | | | |
| 35 | In the past month, I've used gloves in the lab never/always | | | |
| 9 | In the past month, I've won a lab coat in the lab never/always | | | |

Attitude Toward Training

| Item # | Statement | Retain? | Delete? | Revise? Comments |
|---|---|---|---|---|
| 4 | Lab safety training is boring/interesting | | | |
| 32 | Lab safety training is worthless/valuable | | | |
| 14 | Lab safety training gives me useful information strongly disagree/strongly agree | | | |
| 36 | Lab safety training is harmful/beneficial | | | |

Behavioral Beliefs

| Item # | Statement | Retain? | Delete? | Revise? Comments |
|---|---|---|---|---|
| 26 | Wearing a lab coat helps protect me from chemicals strongly disagree/strongly agree | | | |
| 2 | I need to wear gloves to protect myself in the lab strongly disagree/strongly agree | | | |
| 10 | Wearing gloves interferes with my lab work strongly disagree/strongly agree (reverse coded) | | | |

Evaluation of Outcome

| Item # | Statement | Retain? | Delete? | Revise? Comments |
|---|---|---|---|---|
| 28 | I want to protect myself from chemical exposure strongly disagree/strongly agree | | | |
| 15 | Wearing eye protection in the lab is not important/very important | | | |
| 29 | I need to get my work done even if I don't have the right eye protection strongly disagree/strongly agree (reverse coded) | | | |

Normative Beliefs

| Item # | Statement | Retain? | Delete? | Revise? Comments |
|---|---|---|---|---|
| 23 | My lab supervisor wants me to wear a lab coat never/always | | | |
| 8 | My co-workers would approve if I wore eye protection strongly disagree/strongly agree | | | |
| 24 | My lab supervisor doesn't care if I wear gloves or not strongly disagree/strongly agree | | | |

Motivation to Comply

| Item # | Statement | Retain? | Delete? | Revise? Comments |
|---|---|---|---|---|
| 37 | Doing what my lab supervisor tells me to do is not important/important | | | |
| 18 | I want my co-workers to approve of me strongly disagree/strongly agree | | | |
| 1 | I want to please my lab supervisor never/always | | | |

Control Beliefs

| Item # | Statement | Retain? | Delete? | Revise? Comments |
|---|---|---|---|---|
| 11 | I have a lab coat to wear strongly disagree/strongly agree | | | |
| 31 | I have eye protection that fits me strongly disagree/strongly agree | | | |
| 20 | There are gloves available in my lab strongly disagree/strongly agree | | | |

Perceived Power

| Item # | Statement | Retain? | Delete? | Revise? Comments |
|---|---|---|---|---|
| 12 | If I use too many gloves, my lab supervisor will be angry strongly disagree/strongly agree (reverse coded) | | | |
| 33 | I don't know how to get my lab coat cleaned strongly disagree/strongly agree (reverse coded) | | | |
| 27 | I don't have time to wear eye protection strongly disagree/strongly agree (reverse coded) | | | |

# Personal Protective Equipment and Safety Training

*This survey is anonymous, so please don't put your name or other identifying information on the form.*

This survey is about the personal protective equipment you might use in a lab, and about lab safety training.

When we say "your lab supervisor," we mean the person who tells you what to do when you work in a lab; that could be a professor, a postdoc, a staff member, or a grad student.

When we say "eye protection," we mean safety glasses, or safety goggles, or a face shield.

Please put a ✓ or a X on the line next to your group:

1. Your age range:
   ___ Under 20
   ___ 21 to 30
   ___ 31 to 40
   ___ 41 to 50
   ___ 51 to 60
   ___ Over 60

2. Your gender:
   ___ Female
   ___ Male

3. Your status at SIU:
   ___ Undergraduate student
   ___ Graduate student
   ___ Staff
   ___ Faculty

4. Number of lab safety training sessions you have attended while at SIU:
   ___ One
   ___ Two
   ___ Three
   ___ Four or more

Please put a ✓ or a X on the line that reflects your opinion:

5. I want to please my lab supervisor:

| ___ | ___ | ___ | ___ | ___ | ___ | ___ |
|---|---|---|---|---|---|---|
| Never | | Sometimes | | Usually | | Always |

6. I need to wear gloves to protect myself in the lab.

| ___ | ___ | ___ | ___ | ___ | ___ | ___ |
|---|---|---|---|---|---|---|
| Strongly Disagree | | | | | | Strongly Agree |

7. Wearing a lab coat is:

| ___ | ___ | ___ | ___ | ___ | ___ | ___ |
|---|---|---|---|---|---|---|
| Worthless | | | | | | Valuable |

8. Lab safety training is:

| ___ | ___ | ___ | ___ | ___ | ___ | ___ |
|---|---|---|---|---|---|---|
| Worthless | | | | | | Valuable |

9. For me to wear eye protection in the lab is:

| ___ | ___ | ___ | ___ | ___ | ___ | ___ |
|---|---|---|---|---|---|---|
| Impossible | | | | | | Possible |

10. Wearing eye protection in the lab is:

| ___ | ___ | ___ | ___ | ___ | ___ | ___ |
|---|---|---|---|---|---|---|
| Unnecessary | | | | | | Necessary |

11. In the next month, I'm going to use gloves when I handle chemicals:

| ___ | ___ | ___ | ___ | ___ | ___ | ___ |
|---|---|---|---|---|---|---|
| Never | | Sometimes | | Usually | | Always |

12. My co-workers would approve if I wore eye protection.

| ___ | ___ | ___ | ___ | ___ | ___ | ___ |
|---|---|---|---|---|---|---|
| Strongly Disagree | | | | | | Strongly Agree |

13. In the past month, I've worn a lab coat in the lab:

| ___ Never | ___ | ___ Sometimes | ___ | ___ Usually | ___ | ___ Always |
|---|---|---|---|---|---|---|

14. Wearing gloves interferes with my lab work.

| ___ Strongly Disagree | ___ | ___ | ___ | ___ | ___ | ___ Strongly Agree |
|---|---|---|---|---|---|---|

15. I have a lab coat to wear.

| ___ Strongly Disagree | ___ | ___ | ___ | ___ | ___ | ___ Strongly Agree |
|---|---|---|---|---|---|---|

16. If I use too many gloves, my lab supervisor will be angry.

| ___ Strongly Disagree | ___ | ___ | ___ | ___ | ___ | ___ Strongly Agree |
|---|---|---|---|---|---|---|

17. My lab supervisor wears closed-toe shoes in the lab:

| ___ Never | ___ | ___ Sometimes | ___ | ___ Usually | ___ | ___ Always |
|---|---|---|---|---|---|---|

18. Lab safety training gives me useful information:

| ___ Never | ___ | ___ Sometimes | ___ | ___ Usually | ___ | ___ Always |
|---|---|---|---|---|---|---|

19. Wearing eye protection in the lab is:

| ___ Not important | ___ | ___ | ___ | ___ | ___ | ___ Important |
|---|---|---|---|---|---|---|

20. In the next month, I plan to wear eye protection in the lab:

| ___ Never | ___ | ___ Sometimes | ___ | ___ Usually | ___ | ___ Always |
|---|---|---|---|---|---|---|

21. My lab co-workers wear a lab coat:

| ___ Never | ___ | ___ Sometimes | ___ | ___ Usually | ___ | ___ Always |
|---|---|---|---|---|---|---|

22. I want my co-workers to approve of me.

| Strongly Disagree | | | | | | Strongly Agree |
|---|---|---|---|---|---|---|
| ___ | ___ | ___ | ___ | ___ | ___ | ___ |

23. In the past month, I've worn eye protection in the lab:

| Never | | Sometimes | | Usually | | Always |
|---|---|---|---|---|---|---|
| ___ | ___ | ___ | ___ | ___ | ___ | ___ |

24. There are gloves available in my lab.

| Strongly Disagree | | | | | | Strongly Agree |
|---|---|---|---|---|---|---|
| ___ | ___ | ___ | ___ | ___ | ___ | ___ |

25. If I needed to, I could use a fire extinguisher in the lab:

| Definitely False | | | | | | Definitely True |
|---|---|---|---|---|---|---|
| ___ | ___ | ___ | ___ | ___ | ___ | ___ |

26. It's mostly up to me whether I use gloves in the lab:

| Strongly Disagree | | | | | | Strongly Agree |
|---|---|---|---|---|---|---|
| ___ | ___ | ___ | ___ | ___ | ___ | ___ |

27. My lab supervisor wants me to wear a lab coat:

| Never | | Sometimes | | Usually | | Always |
|---|---|---|---|---|---|---|
| ___ | ___ | ___ | ___ | ___ | ___ | ___ |

28. My lab supervisor doesn't care if I wear gloves or not.

| Strongly Disagree | | | | | | Strongly Agree |
|---|---|---|---|---|---|---|
| ___ | ___ | ___ | ___ | ___ | ___ | ___ |

29. In the next month, I'm going to try to wear a lab coat in the lab:

| Never | | Sometimes | | Usually | | Always |
|---|---|---|---|---|---|---|
| ___ | ___ | ___ | ___ | ___ | ___ | ___ |

30. Wearing a lab coat helps protect me from chemicals.

| ___ | ___ | ___ | ___ | ___ | ___ | ___ |
|---|---|---|---|---|---|---|
| Strongly Disagree | | | | | | Strongly Agree |

31. I don't have time to wear eye protection.

| ___ | ___ | ___ | ___ | ___ | ___ | ___ |
|---|---|---|---|---|---|---|
| Strongly Disagree | | | | | | Strongly Agree |

32. I want to protect myself from chemicals.

| ___ | ___ | ___ | ___ | ___ | ___ | ___ |
|---|---|---|---|---|---|---|
| Strongly Disagree | | | | | | Strongly Agree |

33. I need to get my lab work done even if I don't have the right eye protection.

| ___ | ___ | ___ | ___ | ___ | ___ | ___ |
|---|---|---|---|---|---|---|
| Strongly Disagree | | | | | | Strongly Agree |

34. Using gloves in the lab is:

| ___ | ___ | ___ | ___ | ___ | ___ | ___ |
|---|---|---|---|---|---|---|
| Inconvenient | | | | | | Convenient |

35. I have eye protection that fits me.

| ___ | ___ | ___ | ___ | ___ | ___ | ___ |
|---|---|---|---|---|---|---|
| Strongly Disagree | | | | | | Strongly Agree |

36. Lab safety training is:

| ___ | ___ | ___ | ___ | ___ | ___ | ___ |
|---|---|---|---|---|---|---|
| Worthless | | | | | | Valuable |

37. I don't know how to get my lab coat cleaned.

| ___ | ___ | ___ | ___ | ___ | ___ | ___ |
|---|---|---|---|---|---|---|
| Strongly Disagree | | | | | | Strongly Agree |

38. My lab supervisor thinks I should wear eye protection in the lab:

| Never | ___ | Sometimes | ___ | Usually | ___ | Always |
|---|---|---|---|---|---|---|

39. In the past month, I've used gloves in the lab:

| Never | ___ | Sometimes | ___ | Usually | ___ | Always |
|---|---|---|---|---|---|---|

40. Lab safety training is:

| Harmful | ___ | ___ | Neither | ___ | ___ | Beneficial |
|---|---|---|---|---|---|---|

41. Doing what my lab supervisor tells me to do is:

| Not important | ___ | ___ | ___ | ___ | ___ | Important |
|---|---|---|---|---|---|---|

42. Wearing closed-toe shoes in the lab is:

| Harmful | ___ | ___ | Neither | ___ | ___ | Beneficial |
|---|---|---|---|---|---|---|

43. My lab is a safe place to work.

| Strongly Disagree | ___ | ___ | ___ | ___ | ___ | Strongly Agree |
|---|---|---|---|---|---|---|

Finally, please mark **ALL** of the answers that apply to you:

_____ I have never been hurt in a lab.

_____ I have seen someone else get hurt in lab, but just a minor injury, like a cut or burn, that didn't require a doctor visit.

_____ I have been hurt in a lab, but just a minor injury, like a cut or a burn, that didn't require a doctor visit.

_____ I have breathed in chemical fumes that made me feel sick in the lab.

_____ I have seen someone else get hurt in a lab, and it was a major injury that required a doctor visit.

_____ I have been hurt in a lab, and it was a major injury that required a doctor visit.

# VITA

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