INFORMATION, COMMUNICATION, AND CULTURE IN THE MANAGEMENT OF ACADEMIC LABORATORY CHEMICALS

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ABSTRACT OF A DISSERTATION SUBMITTED TO THE FACULTY OF THE
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ABSTRACT

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Objectives

The objective of this dissertation is to understand factors that affect the adoption of chemical management policies in academic laboratories ranging from reduction of wastes through chemical surplus sharing (CSS), provision of health and safety information through web-based sources and creation of safety cultures in response to accidents. The findings of these papers provide information for academic environmental health and safety (EHS) professionals, chemical managers and policy makers that can improve chemical management and health and safety in academic laboratories.

Design/Methods

Three research projects were conducted for this dissertation.

The first paper is an investigation of CSS conducted using a survey with statistical analysis. Information was collected from EHS personnel at institutions of higher education where CSS programs have been in place. Respondents at many of these institutions considered their CSS programs successful. This investigation derived criteria for evaluating the success of a CSS program and identified elements critical for program success.

The second paper examines the utility of chemical information for laboratory personnel which consisted of a multi-pronged web-based exercise. The study used interviews, hypothetical problem sets and observations to document subjects' experience with and reactions to chemical information presented on several websites to determine the embeddedness of the information. Both technically trained (graduate students) and non-technically trained personnel (custodians, laboratory technicians and glassware washers)

who come into contact with chemicals at two major research universities in Massachusetts were recruited to participate in this exercise.

The third project was a case study conducted using qualitative analysis to investigate the relationship between laboratory accidents and safety culture. Interviews with stakeholders, including EHS directors, staff, regulators and students, who have key roles in minimizing laboratory risks, were conducted at three institutions where laboratory accidents have occurred. The goal was to determine whether changes made by the institutions resulting from the accidents addressed the causes of the accidents and were sufficient to promote a strong safety culture.

Setting

The setting for this dissertation was academic institutions; particularly environmental health and safety departments and chemistry laboratories at those institutions.

Main Outcome

Communication, information, and culture play critical roles in university laboratories. Exchange of information facilitates best practices such as waste minimization, assessment of hazards and promotes safety culture. The research discovered how information can modify and improve the way ongoing activities such as purchasing, hazard identification, and training are undertaken, and how information can impact chemical management policies, worker/student understanding of risk, and overall safety culture. The research suggests that management commitment to safety is a prerequisite for the successful adoption of these practices and policies.

Results

Paper 1 research documents that the use of CSS programs exist at many universities in North America. These programs have the potential to minimize hazardous waste and reduce costs associated with waste disposal to the university by reducing the amount of chemicals purchased and later disposed of as hazardous waste. This investigation derived criteria for evaluating the success of a CSS program and identified elements critical for program success. The key factors associated with success included communication in the form of advertising, and information in the forms of chemical inventory and website access played critical roles in successful CSS programs.

The goal of Paper 2 was to investigate whether access to alternative sources of chemical information can increase the awareness and understanding of chemical hazards and improve the effectiveness of chemical management in university research laboratories. The research provided insight into the benefits and characteristics of enhanced chemical safety information for students and lab workers. The research found that for web-based information to be useful and actionable, it must be embedded in the search routines of lab personnel. That is the information must be in the right place, in the right format, at the right time. Subjects valued sites significantly differently based on their perceptions of embeddedness. Their ratings affected their stated desire to return to the sites in the future with the exception of Google. The research also found that Google dominates searches for web-based information and that for alternative sources to be found, they must rank high in Google searches. Purveyors of web-based information should consider this when designing sites.

Paper 3 examined three academic laboratory accidents and the changes that came about as a result of the accidents at each institution and their impact on safety culture there and elsewhere. Regulatory structures intended to oversee university laboratories and their precautionary effectiveness were also assessed. This investigation confirmed that accidents are catalysts for changes in safety practice. In each case studied, the accident ushered in improvements in EHS practice at that institution. Because of the accessibility of news and communication avenues these accidents have an impact on other academic institutions as well.

Safety culture was found to consist of procedural elements and behavioral elements. The procedural elements were found to be in the safety climate category and the behavioral elements were in the safety culture category. Communication was found to be a tool that is integral to the safety culture and safety practice at any institution. Internal communication represents a ready-made vehicle for promoting transparency, waste minimization, hazard and emergency planning.

Conclusion

Staff and students in academic laboratories face a host of risks arising from exposures to chemicals they are using. Effective efforts to reduce these risks require policies and practices that provide them with information on relevant techniques, on chemical hazards, and on procedures that reduce chemical waste and the likelihood of accidents. Equally, they require a strong safety culture that promotes communication among students and staff and is built on management commitment to safety and adoption of best practices.

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TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

CHAPTER II

CHAPTER III

LIST OF ILLUSTRATIONS

CHAPTER I

CHAPTER II

CHAPTER III

LIST OF TABLES

CHAPTER I

CHAPTER II

CHAPTER III

OVERALL INTRODUCTION TO THE DISSERTATION

THE ROLE OF INFORMATION IN LABORATORY CULTURE: WORKING TO IMPROVE CHEMICAL MANAGEMENT AND CHEMICAL SAFETY IN ACADEMIC LABORATORIES.

Problem and Context

Academic laboratories have complicated chemical management issues. This dissertation aims to provide health and safety practitioners with new and useful information and tools to improve chemical management and health and safety in academic laboratories. It focuses on the role of communication, information and culture in promoting chemical management and environmental health and safety in academic environments.

In the United States, 80% of college undergraduates in recent years study sciences and over 100,000 graduate degrees were awarded in sciences from degree granting institutions in 2008 and 2009(1). Many of these students spend a great deal of time in university laboratories in the course of pursuing their degree. There are also custodial and laboratory staff in these institutions who work with and around laboratory chemicals. These people are on the front lines of chemical interactions. Every day they must make choices ranging from purchasing chemicals, handling chemicals, disposing of chemicals. Learning how to handle chemicals safely is a part of science education and this type of lesson is one that shapes the habits that students (in particular) carry into the work force.

Much discussion has taken place in the American Chemical Society (ACS) about the lack of safety preparation found in science graduates of universities. In addition because of overbuying, the many chemicals used in academic laboratories are often disposed of as unknown hazardous waste. Both of these situations occur because of the culture of academic laboratories, which engenders certain habits and attitudes that are both wasteful and risky. And this risk is real. The Laboratory Safety Institute's Virtual Memorial Wall lists five deaths caused by academic laboratory accidents since 2001(2).

Actions of students and workers in academic laboratories are influenced by forces that are associated with the typical academic science environment. These include laboratory culture which includes hierarchical relationships amongst laboratory personnel, easy access to chemicals over the internet, youthful overconfidence towards risk(3), ignorance of budgetary impacts of hazardous waste disposal, and easy access to the internet for acquiring information. The problem of overdependence on "Google" was demonstrated in a recent study of Illinois college students entitled "Libraries and Student Culture: What We Now Know"(4), found that student's research habits exhibit significant deficiencies. In this study, most students were unaware of the extent of their own information illiteracy and some overestimated their ability and knowledge.

Context

The context of this research is a university setting, which has many instances of chemical use, from cleaning materials used throughout the university, mercury and asbestos in collections of historical instruments, to silane in nanoscale research labs. Within this environment, there are opportunities for teaching young scientists and staff people safe and sustainable practices, for changing behaviors using improved information about toxic chemicals, for sharing of surplus materials to reduce waste, for using enhanced health and safety information and for teaching safe practices. Susan Silbey, in recent work sponsored by the National Science Foundation, examined the implementation of an environmental management system in biology and chemistry laboratories at a major university. She found that the organization of laboratories, inherent to the study of different sciences influences the culture and adaptation of the management system (5). The laboratory culture influences safety practices experienced by students and workers in the lab different labs adapted to the system in various ways. Some laboratories were more safety conscious than others, some are not.

Aim and Themes

A goal of this dissertation is to investigate the management of chemical risks in academic laboratories. This research involves investigation of the role of communication, information and culture in reducing risks to students and staff in laboratories. The roles that each of these components play in chemical management are investigated in three studies. The first involves an exploration of the part chemical information and communication play in reducing hazardous waste through chemical surplus sharing. The second study explores available web-based health and safety information as an alternative to material safety data sheets (MSDS). This study incorporates consideration of cultural issues. The third study investigates three university laboratory accidents and how those accidents influence safety culture at those institutions and beyond. This dissertation aims to provide health and safety practitioners with tools to improve chemical management and health and safety practice in academic laboratories.

This study examines how information can be used to help people make decisions about chemical purchases such as modify procurement of toxic chemicals, reduce exposures to hazardous materials, and reduce waste. It examines how web-based safety information can provide useful support to researchers and staff in chemical laboratories. It also examines the critical role that information plays in safety culture.

Hypotheses

The following list contains the hypotheses tested in this dissertation. All three relate to the role that information plays in creating safer chemical management in university laboratories. The role of chemical information is examined from three perspectives in this dissertation, waste management and minimization, personal safety awareness, and safety management.

1. Communication and the accessibility of information play a crucial role in the success of chemical surplus sharing programs.
2. Embeddedness plays a crucial role in establishing website preferences for participants seeking chemical health and safety information.
3. Accidents act as catalysts to improve safety practices within and outside of the university and two-way communication plays a significant role in laboratory safety culture.

Organization of this Dissertation

The three essays in this dissertation cover aspects of environmental health and safety practice in academic institutions which have implications for chemical and health and research safety management. The first essay addresses surplus laboratory chemicals and presents a survey of how institutions are creating programs to make surplus chemicals available to other researchers who can use them instead of adding them to the hazardous waste stream. The second essay investigates the characteristics of web-based chemical safety information that makes it embeddedable and whether those characteristics influence future chemical use and handling choices. The third paper evaluates three academic institutions that have experienced laboratory accidents and assesses the impact of those incidents on the institution's safety culture.

Description of Sections

Part 1: Chemical Surplus Sharing Programs

Hypothesis 1 is tested in Part 1. Many universities have tried and are currently implementing Chemical Surplus Sharing (CSS) programs to reduce laboratory wastes. CSS programs are systems that universities implement to minimize the amounts of incompletely used and unused chemicals from being discarded as hazardous waste through "sharing". These programs have potential to impact both the amounts of chemicals purchased and later disposed of as hazardous waste. In Paper 1, information was collected from EHS personnel at 32 institutions of higher education where CSS programs have been tried. Respondents at many institutions considered their CSS programs successful. This investigation derived criteria for evaluating the success of a CSS program. Information was collected on the workings of the CSS programs, on the on the elements that the respondents feel are responsible for the success of the program, and on the elements they see as barriers to successful programs.

Part 2: Transparency and Chemical Health and Safety

This project investigates the impact of web-based chemical health and safety information on the awareness and understanding of hazards of laboratory chemicals among laboratory workers and students. It evaluates which characteristics make websites useful to the subjects of the study. Seven websites are assessed for their ability to provide useful health and safety information to laboratory workers and students using three criteria: relevance, compatibility and accessibility.

The purpose of this research project is to explore the concept of embeddedness in the context of chemical health and safety in university laboratories. Embeddedness is defined as the ability for information to be retained, absorbed, and integrated into one's consciousness and for that information to be assimilated and internalized. When information is "embedded", it is taken to heart and can cause a change in behavior.

The goals of the project are to explore the role that embeddedness plays in establishing website preferences in participants seeking chemical health and safety information; to explore whether website preferences identified predict future behavior; and to determine whether there are differences between students and workers in website preferences and predictions of future behavior.

Seven websites that provide chemical health and safety information were investigated. Thirty-five participants who work or study around chemicals in academic laboratories at University of Massachusetts Lowell and Harvard University were recruited for this study including students and workers from both institutions.

The investigation tests the hypothesis that exposure to transparent chemical health and safety information sources can embed these sources of information critical to the assessment of workplace risks and the management of laboratory chemicals in the minds of people who need them. It examines whether the availability of enhanced chemical health and safety information can increase the understanding of chemical hazards and improve decision-making about chemical management in research laboratories at universities.

Part 3: The Impact of Chemical Accidents on Safety Culture and Practice

This project examines the impact of laboratory accidents on safety culture and practice and in particular the impact of transparency about the accidents. Several high profile accidents took place within 2009 and 2010 which brought attention to the issues of laboratory safety. Case studies of two accidents that occurred recently and one that occurred in 1997 were evaluated using a safety culture framework derived for academic institutions. The experience of documenting the causes of the accident and the remedies impacted safety practice and culture not only in the institutions where the accident occurred but in the larger academic community. Factors included in the safety culture model include procedures such as communication, inspections, training and record-keeping, and values, such as management commitment to safety, accountability and transparency. Regulatory structures that are supposed to provide oversight to university health and safety programs and their effectiveness or lack thereof in preventing accidents were also examined.

Research Design and Methods

The dissertation explores the role of information and communication of that information in laboratory safety and chemical management in academic environments. The study is a multi-faceted investigation of a set of related hypotheses.

Both qualitative and quantitative research methods are used in this study. The first two chapters use quantitative analyses to evaluate the data collected. The third paper uses a comparative case study method and the analysis was done qualitatively. The study designs and methods are described in detail in each chapter. Each chapter concludes with the findings of that project.

The final chapter of this study summarizes the findings and provides a policy evaluation for information management and the regulatory framework under which academic chemical management falls and suggests ways that this might be improved. The final chapter also provides conclusions, recommendations and directions for future research.

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CHAPTER I

SECRETS REVEALED: CHEMICAL SURPLUS SHARING AT COLLEGES AND UNIVERSITIES

INTRODUCTION – BACKGROUND

In this age of sustainability, many colleges and universities are taking actions to reduce environmental impacts arising from university operations. In response many institutions have hired sustainability coordinators who look for ways for the university to become more sustainable. One area that has been of great concern for many years is the generation of hazardous wastes by research and instructional laboratories. Because of the nature of scientific research, many types of chemicals are purchased by laboratories for experiments. The requirement to accommodate such varied use involves management of chemical inventory and disposal which generates large quantities of hazardous wastes in the form of chemical wastes (1). This problem is recognized by Resource Conservation and Recovery Act (RCRA) and Occupational Safety and Health Act (OSHA) regulations that attempt to deal with this issue – RCRA on the waste issues and OSHA on health and safety regulations. To be sustainable, universities must adopt efforts to manage and reduce their wastes such as recycling, reuse and exchange. Universities also seek to reduce costs associated with disposal of hazardous wastes generated by the research laboratories. Efforts to manage and reduce chemical wastes were described extensively in the 1996 volume "Pollution Prevention and Waste Minimization in Laboratories (2). The hierarchy of toxic use reduction and waste minimization includes process modification, improved operation and material substitution as the first tier and chemical exchange as the second tier. Chemical surplus sharing (CSS) programs are examples of waste minimization. Because by making excess chemicals available to other researchers through CSS, fewer chemicals need to be purchased and fewer chemicals enter the waste stream as hazardous waste.

Typical CSS Programs

A typical CSS program in a college or university consists of an effort to keep unused or incompletely used chemicals from laboratories out of the waste stream by making these chemicals available to other researchers for little or no cost. Chemicals are gathered through donation, through weekly hazardous waste pickup, and during lab cleanouts. They are screened by Environmental Health and Safety (EHS) personnel and rules determine which chemicals are included and how long chemicals are kept in surplus. In many schools, the surplus chemicals are kept in a separate secure storage area. However, some schools keep the surplus list virtual and the surplus chemicals are labeled or otherwise designated and stored in the labs from which they are donated. In many schools, surplus chemicals are tracked using an inventory program and posted on a website. Customers request the surplus chemicals using email or via a website. EHS delivers the chemicals to the customer.

Benefits of CSS

CSS programs have great promise for intercepting materials from laboratory waste streams. Many research laboratories use hazardous chemicals to carry out their research. And hazardous chemicals, if improperly handled can cause pollution and present risks to health, safety and the environment (1).The improper use and disposal of chemicals may impact the university community and the surrounding community. Hazardous waste disposal costs universities directly. For example, not including labor and operating costs, the University of Maryland spends nearly $100,000 annually to safely dispose of chemical waste commercially. Each carboy costs up to $20 to dispose of; disposal of *one* lecture bottle (a small gas cylinder) can cost up to $1,600. Reduction of hazardous waste through CSS also can reduce costs such as these – which are typical for academic institutions. By putting the chemical in a surplus inventory and making it available to secondary users, the chemical stays out of the waste stream, saving the university or the department the funds they would otherwise have to spend on disposal of the chemical waste and the adopter gets free chemicals. It is a win- win situation. The cost for disposal is saved. The new customer saves the cost of buying a new chemical.

Examples of CSS Programs

There are institutional variations of CSS programs. One idea for chemical exchange is simply to maintain an online inventory of unused reagent chemicals which can be given to or shared with other laboratories. This keeps surplus materials from being unnecessarily discarded. This surplus can be stored in a special stockroom where unused reagents can be returned and offered to others. Alternatively, a material exchange website containing "available" and "wanted" listings can be created as part of an inventory control system (3, 4). The surplus can be stored in the original laboratory until someone wants it or it expires. So a separate storage location may not be necessary.

Many universities have tried CSS programs. These programs have potential to reduce the amount of chemicals purchased and later disposed of as hazardous waste. The programs generally make surplus chemicals available for free which saves the individual laboratories money as well. Some programs are successful in a measurable way. For example, a chemical sharing database at University of British Columbia, launched in 2004, processed 300 exchanges (1,500 kilograms in chemicals) last year alone and has helped to save an estimated $74,500 in disposal and purchasing costs. In other waste minimization efforts, UBC recycled more than 8,000 liters in solvents and 5,000 liters in photographic waste annually (5). Many universities use chemical inventories to keep track of chemicals and surplus. Universities such as the University of Washington are required to keep a chemical inventory for all chemical storage and use locations. The inventory must be entered online in a database to comply with local, state and federal regulations (6).

Information Collected for this Project

Information from Environmental Health and Safety (EH&S) personnel at 32 institutions of higher education where CSS programs have been tried was collected for this investigation. Information was collected via a questionnaire. Respondents at many of these institutions considered their CSS programs successful. But in some cases, the programs failed. At two schools, long-running programs failed. The questionnaire collected data on the workings of the CSS programs at different institutions, on the on the elements that the respondents feel are responsible for the success of the program, and on the elements they see as barriers to successful programs. We examined the relationships of institutional factors such as number of laboratories, size of campus and setting to program characteristics. We also investigated the importance of communication and information exchange in chemical management and what forms it takes in CSS programs.

Objectives

The main goals of this investigation are: 1. to define criteria for evaluating the success of CSS programs and, 2. to rate those elements that determine the program's success. A specific sub-objective related to these goals is to evaluate how information and communication help make CSS programs successful.

Literature Review

Many people have written about CSS programs. The following summaries of a few previous studies provide the background for this study.

Peter Reinhardt wrote about redistribution of surplus chemicals and CSS program that had been started at Wisconsin in 1980 (2). A study in 1980 found many unwanted chemicals in their original packaging. He wrote that as he was writing in 1994, surplus chemicals were still a significant waste stream at Wisconsin. The CSS program (called LabSCAN) was very successful in 1994 (and still is today). He estimated that about 30 to 50% of the surplus chemicals are redistributed and that this saved the University $10,000 to $20,000 in the cost of purchasing new chemicals and avoidance of disposal costs.

Reinhardt described communication as an important element necessary to facilitate waste minimization (2). He stressed that communication between the safety department and the laboratory personnel was necessary to overcome informational barriers and promote waste minimization.

Similarly in the same volume, Leigh Leonard noted that respondents to a survey of laboratory staff at Howard Hughes Medical institute about waste minimization reported practicing surplus sharing but did not do a good job of documenting their practices, nor their savings (7).

Jeff Christiansen (8) wrote about the CSS program at University of Arizona and the keys to a successful CSS program. He stated that most important factor contributing to the success of a CSS program is publicity. He also wrote that it is important for the program managers to know the laboratory community to understand which chemical will be most useful and in demand. He said that the CSS program should be run like a business. The program should offer good service and good reliable products (8). Christiansen also thought that marketing and training plays a role in a successful program and that every opportunity to educate the chemical-using community about the CSS program should be taken.

He also said that to overcome impediments to exchange of surplus, active participants could be given first change at the new surplus items. Public appreciation for participation could encourage participation (8).

The New England Laboratories Project XL, a project of a consortium of three New England Universities: Boston College, the University of Massachusetts (UMASS)–Boston, and the University of Vermont found the biggest barrier to reuse of surplus chemicals was not regulatory, but cultural. They found significant resistance from laboratory workers to the idea of using chemicals that another lab has identified as waste (9).

Amanda Ogden studied the feasibility of setting up a CSS program at University of Florida (UF) for her Master's Thesis in Engineering (10). For her thesis she designed the UF Chem Swap Program as a web-based system. She described the hurdles from program acceptance as the culture of the laboratory community – i.e., high turnover of the graduate student population and decentralization of the science departments. According to Shriberg (11), Monteith and Sabatini (1997) found that people were supportive of sustainability mantra but when implications became apparent, disparities in approach were found.

RESEARCH DESIGN AND METHODS

This study consisted of an investigation to study the use of chemical information to set up chemical surplus sharing (CSS) programs at major universities. It involved investigation of how surplus chemicals are handled at a group of colleges and universities.

Research Process

The process used to conduct this research consisted of the following steps.

A. Find Study Subjects
   1. Choose study subject institutions.
   2. Identify contacts who could answer questions about the CSS program at each institution.

B. Data Collection
   1. Compose the CSS questionnaire with questions about the institution, the CSS program and their thoughts about the critical elements to making the program work. A copy of the questionnaire is included in Appendix A.
   2. Send out questionnaires. Contact the representative at each institution, explain the project to them and ask them to complete a questionnaire.
   3. Gather the returned questionnaires, Follow up with further questions, if necessary.

C. Data Analysis - Compile the results. Interpret the trends.

Each of these steps is described in detail below. The first steps involved finding the study subjects.

Choosing the study subject institutions

The universe of subjects in the study was environmental safety departments at colleges and universities in North America. The goal was to contact approximately fifty colleges and universities of all sizes, public and private who had tried chemical surplus sharing programs. Identification of these subjects was carried out by various means.

The initial surplus sharing program that was surveyed was that of University of California at Santa Barbara (UCSB). The Laboratory coordinator of the Harvard Office of Sustainability sent the link to their program, run by the Lab Rats, the UCSB name for the campus sustainability group. Contact was made with Katie Maynard. Ms. Maynard, with the help of others, runs the surplus sharing program at UCSB.

The rest of the subject institutions were identified by several methods. They are discussed here.

CSHEMA Forum

One method of obtaining study subjects was to subscribe to the College Safety and Health Management Association (CSHEMA.org) forum. The CSHEMA universe consists of 360 educational institutions, mostly based in the United States. There are several Canadian Schools represented and a few European schools as well. The CSHEMA forum describes itself as ..."an information resource for College and University practitioners in health, safety, environment, sustainability and risk management". (12) The CSHEMA Forum is a service that allows users to interact in real-time, share information, and search for past conversations about any topic. (13) Three queries were sent out to the CSHEMA

Forum. The first query was sent out on October 19. 2009. Two responses to this message were received, one from University of Utah and one from Carnegie Mellon University. A second query was sent out to the forum on November 4, 2009. From this effort, nine schools responded. They included Creighton University, Kansas University Medical School, Mississippi State, Wright State, Arizona State, Bowling Green State and Iowa State.

In a final attempt to use the CSHEMA website to gather subjects, a final message was sent out to the forum on February 15, 2010. No additional responses were obtained in this manner. Given that this avenue of gathering subjects seemed to have dried up, several additional methods were used to find more participants.

Contractor Meeting

Another method used to identify subjects was to schedule a meeting with Mr. Michael Benson, an executive with Triumvirate Environmental. Triumvirate is a service firm that specializes in hazardous waste management for biotechnology, education, healthcare, facilities (14). Mr. Benson was the New England Director of the Higher Education Niche at Triumvirate Environmental. He is the Account Manager for Triumvirate's New England based Higher Education clientele. He manages large college and university hazardous waste programs throughout New England. He provided a list of contacts at these institutions who deal with chemical management. Through Mr. Benson, seven additional contacts were identified. These included UMASS Lowell, Clark University, University of New Hampshire, University of New England, Holy Cross, Dartmouth, Brown and Yale.

Referrals from Contacts

EHS safety officers of some institutions were very helpful in identifying contacts at other universities. One chemical safety officer provided the names of three people at colleges in the Midwest. These were University of Minnesota, University of Illinois, and University of Wisconsin. The safety officer at University of Illinois provided two other contacts, University of Vermont and Michigan State University. Additional contacts were made with University of Washington, University of California at Berkeley, University of Oregon, and University of North Carolina through website searches.

Articles

A few articles about surplus sharing programs were located through a web search. Web-based articles and in a Master's thesis written by Amanda J. Ogden for the Engineering School at UF (10) were identified in this manner. Her thesis summarized the process of setting up an inventory and chemical surplus sharing at UF. Contact with the University of Florida and found that the program described by Amanda was no longer followed and a simpler program has taken its place. The program at University of British Columbia (UBC) was mentioned in an article that was found on the internet (5). Through the website of the UBC program, the current chemical safety officer in charge was identified.

Subjects Identified

Forty schools were the subject of this study. Eight schools were sent questionnaires but they did not complete them. Several of the colleges contacted did not have surplus sharing programs. These schools were not included in the questionnaire-based study but contacts from these schools were interviewed informally about chemical management at their University. Some schools in the sample have abandoned their programs. Boston

University for example, did not have a surplus sharing program per se but has solvent recycling. Bowling Green State University has a unique program of surplus sharing with entities inside and outside of the university. These are variations on the surplus sharing spectrum that will not be discussed in this paper.

The Final List of Subjects

Table 1 summarizes the schools from which data were collected. The data in this table were obtained for each institution from various sources on the internet. Basic information on the institutions is available on most of the institution websites. The information obtainable in this manner is the acreage and the location and setting of the campus. Statistics on colleges are also obtainable through several web-based sources. They are: U.S. News and World Report College Rankings (2010) (15), IPEDS Database (US Department of Education, 2010) (16) college web pages. The statistics gained from these sources were checked against the information available on the individual institution website. If something could not be gleaned from the internet, the institution contact was emailed or called again with additional questions.

Identify Contacts

Contacts identified were identified at each institution. These were people who could answer questions about the surplus sharing program that had been attempted at their institution. Contacts who reported abandoned programs were asked to participate in the study because we wanted to identify what the EHS personnel thought were the obstacles to the program's success. Thirty-two completed surveys were received.

Data Collection

The following are steps involved in the collection of data.

Compose CSS Questionnaire

A set of questions was prepared for each university representative. The CSS questionnaire was divided into three sections. The first section contained General Questions. The second section contained questions about how the program works or worked, and the third section contained questions about the Success or Failure of the Program.

Institutional Questions

The first section contained questions on the attributes of the institution and the chemical management system at the university. This section contained thirteen questions including five questions about the institution. The remaining eight questions were about the workings of the chemical management system including whether the institution has a chemical inventory system.

CSS Program Questions

The second section covered the workings of the CSS program. The fourteen questions summarized the characteristics of the program, how the program works, how many departments or laboratories participate, whether the program is supported by the administration, whether a physical space is necessary to store the surplus chemicals, whether they use a website, the types of chemicals that are recycled and how many personnel are required to run the program.

The third section of the questionnaire looked for an interpretation by the respondent as to the factors that contribute to the success of the program and what were the obstacles. The questions were somewhat open ended and a final section asked the responded to provide advice to institutions that want to attempt a surplus sharing program.

Send Out Questionnaires

Data collection took place between December 2009 and June 2010. During that time attempts were made to contact staff at colleges and universities who could answer questions about CSS at their institution. Generally the people who answered the questionnaires were employees of the EHS Office. The staff person in charge of chemical management was contacted. The initial contact was usually by email or telephone.

If the person could not be reached by telephone, an email was sent inquiring as to the best time to contact them by telephone. Usually, a time was agreed upon to call. At that time, either the process below was followed, or if a surplus program was not in place at their institution, additional questions about chemical management at their university were asked and their contact information kept for future research.

If the person could be reached by telephone, they were asked if they had a surplus chemical sharing program. If yes, the goals of the project were explained and they were asked if they would be willing to answer the questionnaire. The questionnaire was then sent via email to the contact person. The email thanked them for participating, summarized the documents included and gave them a deadline of approximately two weeks after the email was sent. Upon sending the email, the contact's name, university, phone number, email address and date were entered into a spreadsheet.

Gather Returned Questionnaires

After receipt of approximately eight questionnaires, the responses were reviewed and the questionnaire revised to request additional recommendations of improvement of programs.

Data Analysis

The surveys received from each institution were assigned individual numbers and each question was evaluated by institution number, without regard for the name of the institution. Three worksheets were created that corresponded to the categories of questions in the survey. A coding sheet was created and each of the answers to the questions coded and entered for each institution. A Master Table was created that contained all the questions and answers. Queries were performed on these data to assess the trends in the data.

Along with qualitative analysis of the survey results, summary statistics were generated for many of the parameters. The study was not based on a random sample of colleges and universities, therefore the results are not representative of the population as a whole. However, the statistical comparison between the 32 respondents provides insight into important variations among schools who participated in the study.

RESULTS

This section summarizes the findings documented by the questionnaire about CSS programs filled out by 32 university contacts. There are three sections of the questionnaire document: 1. characteristics of the institutions in the sample, 2. workings of the CSS programs and finally, 3. opinions of the professionals as to the success or failure of their program and the elements they felt were responsible for this. The main goals of this investigation are: 1. to define criteria for evaluating the success of CSS programs and, 2. to rate those elements that determine the program's success. A specific sub-objective related to these goals is to evaluate how information and communication help make CSS programs successful.

To uncover this, the workings of 32 CSS programs were investigated. The hypothesis with which this investigation began is that communication and the accessibility of information may not be the only important elements but play a crucial role in the success of CSS programs.

Schools in the Sample

The following section summarizes the information compiled on the schools contacted for this investigation. During this investigation 40 public universities and private colleges were contacted and 32 questionnaires were completed. All schools included in the sample had tried CSS. Approximately 15 other schools were contacted but did not complete the questionnaires. Representatives of 22 public universities and 10 private colleges contacted completed questionnaires.

Twenty eight of the schools described ongoing CSS programs. [1] Four schools reported abandoned programs. Twenty one of these programs were formal, institutionally sponsored programs. Eleven in the study were informal programs. Table 1 contains descriptive information about the schools contacted. The information listed in this table was obtained through searches of the college websites. Only the number of laboratories and number of students were obtained from questions in the survey. A little over half of the schools in the sample (18) were located in urban settings. Seven were in suburban settings or small cities, and the rest, six, were in small towns or rural settings.

In Table 1 the highlighted schools are private institutions.

Summary statistics for eight parameters about the sample schools are presented in Table 2. This information was obtained through the questionnaire and through the individual college websites. These parameters indicate the range of institutional sizes in terms of the number of students and the number of laboratories, and physically how large the campuses are. These institutional characteristics are of interest in relation to the scope of the CSS programs in the sample.

[1] In discussing the percentages of answers, generally the denominator is 32– the number of surveys that were filled out. However, not every question was answered in every questionnaire. If the number of responses is much less than 32, it will be noted.

Table 1 Institutions in the Sample

Institutions	Location	Under-graduates	Grad Students	Labs	Setting	Acreage
Private Institutions						
College of the Holy Cross	Worcester, MA	2817	.	30	Urban	175
Creighton University	Omaha, NE	4100	3200	150	Urban	130
Cornell University	Ithaca, NY	13931	6427	3500	Small City	745
Clark University	Worcester, MA	3000	1000	50	Urban	52
Carnegie Mellon University	Pittsburgh, PA	5892	5066	300	Urban	144
Stanford University	Palo Alto, CA	6812	8328	800	Suburban	8,183
Yale University	New Haven, CT	12495	6169	1100	Urban	837
Dartmouth College	Hanover, NH	4196	1791	208	Small town	269
Northeastern University	Boston, MA	15339	5410	425	Urban	73
University of New England	Portland, ME	4000	1068	49	Urban	540
Public Institutions						
University of Illinois	Champaign/Urbana, IL	31000	9600	1600	Small city	1,468
University of California	San Diego	22500	4000	2500	Suburban	1200
University of California	Santa Barbara, CA	18900	2968	770	Suburban	1022
University of California	Berkeley, CA	34000	12000	1500	Urban	6651
University of Arizona	Tucson, AZ	37000	6870	1200	Urban	380
Iowa State University	Ames, IA	28000	4614	1800	Urban	1,984
U Kansas Medical Center	Kansas City, KS	2800	2800	200	Urban	1100
University of	Amherst, MA	20873	6143	900	Rural	1463

Massachusetts						
University of Massachusetts	Lowell, MA	19500	3054	300	Urban	150
Michigan State University	Lansing, MI	47000	9973	1200	Suburban	2000
University of Minnesota	St. Paul, MN	50000	22180	1500	Urban	2730
University of Mississippi	Oxford, MS	14000	.	375	Small Town	.
Missouri State University	Springfield, MO	12800	3200	.	Urban	225
Wright State University	Dayton, OH	17660	3108	350	Suburban	730
University of Wisconsin	Madison, WI	40000	11756	2000	Urban	933
University of Washington	Seattle, WA	50000	12117	2195	Urban	643
University of Vermont	Burlington, VT	9500	1600	400	Small Town	450
University of Utah	Salt Lake City, UT	22149	7155	1000	Urban	1534
University of Oregon	Eugene, OR	22000	3919	130	Urban	295
University of North Carolina	Chapel Hill, NC	28567	233	212	Small city	729
University of New Hampshire	Durham , NH	12000	3000	480	Rural	1,100
University of British Columbia	Vancouver, BC	40000	9350	350	Urban	270

Table 2 Institution Summary Statistics

Parameter	Mean	Median	Minimum	Maximum
Undergraduates	16099	13931	598	42099
Graduate Students	5570	4000	233	22180
Number of Labs	889	480	30	3500
Public number of labs	998	900	130	2500
Private number of labs	661	254	30	3500
Acres	1194	729	52	8183
Public Acres	1230	978	150	6651
Private	1115	222	52	8183

The average institution in the sample had over 10,000 undergraduates, with a median of almost 14,000 students, indicating a predominance of large public universities. But the sample also includes several private colleges with a small number of undergraduates. The range of total graduate students is narrower but the maximum number again belongs to a large public university (University of New Hampshire).

The range in the number of laboratories was very wide. The smallest number of labs in the sample was 30 and the largest is over 100 times that, 3500. The initial thought that the large number of laboratories was exclusively related to the large public universities. Although it is generally true that there are many more laboratories in public universities, in fact, the largest number of laboratories in the sample was found at Cornell University, a private institution. In general the range of number of labs among most private schools in the sample was narrower, Cornell being an outlier. The number of labs in public universities in the sample ranged from minimum of 130 to a maximum of 2,500. This range is smaller than the private school range, with the minimum being 19 times less than the maximum number of labs. The mean and median number of labs in public universities was similar (mean = 998 and median = 900). This suggests that the public universities in this sample are more normally distributed sample.

A measure of the scale required for CSS programs is the number of laboratories at the university. As is the case with numbers of students, there was much variation in the sample, ranging from a low of 30 labs to a maximum of 3500.

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CSS Program Information

Information from the program portion of the questionnaire about the workings of the CSS programs amongst the sample schools is summarized in Tables 3, 4 and 5.

Elements of CSS Programs

Surplus chemicals are gathered from laboratories and in many cases inventoried and labeled as surplus. The chemicals are then kept either on a virtual list or in a surplus storage area. They are "advertised" and distributed to interested parties free of charge.

A typical CSS program works like this: Chemicals are gathered through donation, through weekly hazardous waste pickup, and during lab cleanouts. Chemicals are screened by EHS personnel. Rules determine which chemicals are included and how long chemicals are kept. Certain chemicals such as solvents are more likely to be in demand. Surplus chemicals are kept track of using an inventory program and posted on a website. They are requested by customers through email or via a website. EHS then delivers the

Table 3 CSS Program Characteristics based on Survey Questions

Survey Questions	Number of responses	Percentage
Storage space for surplus chemicals?		
Has a physical storage space (y)	26	81
Does not have a physical storage space	6	19
Where are chemicals stored?		
EHS Facility	12	37.5
Haz Waste Facility	10	31
Chemistry/Science Department	4	12.5
None/NA	6	19
How long are chemicals kept in surplus inventory?		
One year or less	14	47
More than one year	16	53
What types of chemicals are shared?		
All Chemicals are shared	7	26
Variable, limited by permits	8	30
Solvents, Acids	10	37
What types of chemicals are in high demand?		
Hexane and Solvents	11	60
Acids	7	30
Salts and Reagents	2	10

requested chemicals to the customer. By putting the chemical in a surplus inventory and making it available to secondary users, the chemical stays out of the waste stream, saving the university or the department the funds they would otherwise have to spend on disposal of the chemical waste and the adopter gets free chemicals. It is a win- win situation. The cost for disposal is saved. The new customer saves the cost of buying a new chemical.

Table 4 CSS Program Statistics

Characteristic	Mean	Median	Minimum	Maximum
Length of time CSS program functioned (years)	11	10	0	28
Chemicals shared per year (bottles)	314	218	12	1440
Staff required for CSS program	3	3	1	10

Staffing Needs

The CSS programs need a small staff to run them. The staff screen donations for eligible surplus chemicals, pick up and redistribute chemicals. Nineteen respondents (61 %) said that two or fewer EHS or Hazardous Waste staff members were required to run the CSS program. The CSS programs described by respondents employ an average of three staff, depending on the size of the program and the number of participating labs. For small programs (number of labs below the median of 480), the average number of staff is approximately two. For larger programs (number of labs above the median), the average number staff is approximately 3. There is no difference between the number of staff working on CSS in public and private institutions. The maximum number of staff in any program is ten. Some respondents reported help from university sustainability organizations or other campus groups.

Holding Time

Surplus chemicals may remain in the inventory for a while before they are either claimed or disposed. A question regarding the length of time chemicals are kept in the surplus collection resulted in 14 respondents reporting keeping the chemicals in the surplus

Table 5 Methods of Tracking Chemicals

Tracking Method	Number of Responses	Percentage
Inventory		
Full inventory	21	66
Partial inventory	9	28
No inventory	2	6
Website		
Yes	24	75
No	8	25

inventory for a year of less with annual inspections. Sixteen respondents reported keeping the chemicals in the surplus inventory over a year or until they expire.

Numbers and Types of Chemicals Shared

Consistent with Leonard's findings of low levels of program accounting documentation (7), only 11 of 31 people in the study responded to this question about number of bottles shared. Similarly, the documentation of dollars saved was answered only less than half the respondents. Based on the responses the programs in the study shared an average of 314 bottles per year with a median of 218 and a maximum of 1440 bottles. Solvents and hexanes are the chemicals listed as most in demand. Most schools prohibit oxidizers, inhalation poisons and peroxides from being shared.

Physical Storage Space

Twenty-six or 81% of the respondents reported physical storage spaces for surplus chemicals. In this sample, storage of chemicals by EHS occurs within an EHS facility such as a Treatment Storage and Disposal Facility (TSDF)/Hazardous Waste Management Facility (HWMF), or within the chemistry/science department. This is an important consideration – where to store excess. An alternative is to list the excess chemicals online in the inventory but house it in the laboratory where it originates, until someone wants it. About half of the universities with physical storage spaces for the surplus chemicals were in urban settings.

Gathering surplus chemicals

Many (42%) of the respondents reported that technicians gather surplus chemicals from laboratories. They describe that surplus chemicals are obtained from labs in three ways. These methods are not exclusive; in fact surplus chemicals are often received through multiple methods. The three methods are:

1. Through donation. This occurs when there is good communication between the EH&S department and the laboratories. In this situation, labs voluntarily contribute unopened or opened but uncontaminated chemicals by alerting EHS when chemicals are available. Twenty five percent of respondents reported obtaining surplus chemicals through donation.
2. Through weekly hazardous waste pickups. Chemicals are donated when they are determined they are no longer needed. They are identified during rounds to pick up chemicals for disposal. Eleven percent reported surplus being identified during rounds to pick up hazardous waste.

3. During lab cleanouts. Chemicals are gathered when a laboratory closes and the investigator leaves the university. This is a very common way to obtain surplus chemicals. Typically prior to lab clean outs the hazardous waste manager or EHS staff scope out the chemicals and flag them for recycling (usually unused and unopened).Twenty two percent of respondents said that surplus chemicals were obtained during lab cleanouts.

Chemical Inventory

Prior studies suggest that the use of the chemical inventory program enhances the ability to identify surplus chemicals (1). This was found in the sample. Twenty one schools in the study (66%) reported the use of a comprehensive chemical inventory program to keep track of chemicals. Nine more schools (28%) report use of a partial inventory. Altogether, that makes 94% who reported to have some sort of chemical inventory. The presence of a chemical inventory in this sample was positively associated with the length of time a program functioned holding constant the number of laboratories.

Tracking chemical inventory is also necessary for safety management and regulatory compliance. However, this task is especially challenging for diverse and decentralized research and laboratories found at colleges and universities. Safety and compliance, waste minimization, emergency preparedness, and facility planning design all benefit from knowing what chemicals exist at a facility, who has responsibility for them, and where they are located. Managing chemical inventories at colleges and universities has often been identified by EH&S directors as one of the major safety and compliance management challenges for higher education institutions. Tracking chemical inventories goes hand in hand with tracking surplus and minimizing hazardous waste.

Several institutions stressed that labeling chemical bottles as surplus is important to distinguish them from regular inventory. An example of a chemical surplus label has been provided by Northeastern University and is shown in Figure 1.

Figure 1 Northeastern University Recycling Label

Northeastern University
Office of Environmental Health & Safety

170 Cullinane Hall
Boston, Massachusetts 02115
(617) 373-2769
http://www.ehs.neu.edu
Originator Information

Principal Investigator: ______________________
Phone #: ______________ Dept: ______________
Room # / Bldg: ______________ Date: __________
Material to be recycled: ______________________

Website

A majority (75%) of the respondents reported that a website was important to the functioning of the CSS program. The questionnaire asked for and most people provided links to their program website. Some of these were listings of the chemicals available through the CSS program. Many explained the way the program worked and how customers could obtain one of the chemicals on the list. Most of the websites that were listed were only available to students or staff with valid identification. Two websites from the sample population stand out as innovative and creative and have done much to boost the renown of their CSS programs. These are the two websites from Iowa State University and from University of California at Santa Barbara. Both of these are set up like a commercial website with pictures of the chemical, a short description, a search function and a shopping cart. They resemble a screen you might see on Craigslist© or Amazon.com©. A screen shot of one website is provided as Figure 2.

A website is an efficient and effective way to advertise the chemicals available in the surplus collection. If the website is set up to do this, it can be a vehicle of communication between EH&S and customers. A majority of the respondents (24 or 75%) reported having a website.

Distribution of chemicals to secondary users

Sixteen respondents (50%) reported that surplus chemicals are posted on a website or posted near the laboratories and/or email alerts are sent out to prospective users. In one case available chemicals stay in the original laboratories and are labeled surplus on the bottle (see label above). In many cases (34%) the chemicals were stored in stockrooms or in a hazardous waste facility. Commonly, potential new users request the chemicals (by calling EHS or by indicating their request on the website). EHS alerts the new user that a chemical is available (via phone or email) and either EHS transports the chemicals to the new user or the new user picks them up.

A few programs exchange of chemicals outside of the university (BGSTATE). This process involves special legal and regulatory considerations. Such concerns are liability and transport of hazardous chemicals on public roads.[2]

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[2] This type of exchange is not discussed here but information is available through the following universities: Bowling Green State, U Washington, UCSD.

Measures of Success

One of the goals of this investigation was to learn how to evaluate success of a CSS program. In order to judge how successful a CSS program is, the criteria for measuring program success must be determined. From discussions with subjects of this investigation and from the responses to the questionnaire, the following four elements can be used as measures of the success of a CSS program. 1. Participation Rate, 2. Money saved by the program, 3. Amount of chemicals kept out of the waste stream, and 4. The longevity of the program. Several questions in the questionnaire addressed these success measures. A summary of the sample group responses to questions regarding these four parameters is provided below.

Participation rate

Positive responses to the question about participation rates (percent of laboratories participating in surplus sharing), ranged from one percent to 100 percent. The most common response, answered by 11 of the 32 respondents, was that participation was over 50 percent. This includes 10 that reported 100% participation. This could be interpreted as the program is available to all labs, or it could be interpreted as everyone actively participates.

The second most common response, reported by 10 of the 32 respondents (30%) was that less than four percent of all labs participate in surplus sharing. This group includes five who responded "na". Eleven responses as to laboratory participation were 5% through 19%. As a group, participation rates less than 20% were very common in the sample accounting for 68% of the sample (22/32 responses). This is shown in Figure 3.

Money Saved

The issue of money saved through CSS was addressed in the questionnaire by a question about the financial benefit of CSS. This question asked the respondents for an estimate of the money saved by keeping surplus out of the waste stream. The question was answered by 29 respondents. Thirteen of these respondents (41%) reported that there was nofinancial benefit to surplus sharing. Five respondents answered that the amount saved was insignificant. The remaining positive responses ranged from $50 per year to $31,456. Six institutions had estimates of savings over $15,000.

The highest savings reported from preventing items from entering the waste stream was $31,456 in one year. Only nine respondents answered this question. An explanation for this low response rate could be the fact that contractors often are responsible for hazardous waste removal. Items kept out of the waste stream may not be accounted for in the bill. The failure to document savings for this reason makes it more difficult for EHS and other departments to gain support for chemical sharing efforts.

Amount of Chemicals Shared

This question, related question to the money saved, is the amount of chemicals shared and therefore kept out of the waste stream. This question was answered by 12 respondents. Twenty respondents answered "na". From those who did report bottles kept out of the waste stream, the number of bottles shared ranged from 39 to 3000. Five respondents reported sharing less than 50 bottles per year. Two respondents reported sharing between 51 and 1000 bottles per year and four reported sharing between 1000 and 3000 bottles. Similar to the question about money saved, many of the institutions were not able to provide this information. This could be because large quantity generators do not track chemicals disposed of in the original container (4).

Longevity of the CSS program

The length of time a program has been functioning is a testament to the dedication of the EHS staff to keep it going and possibly to the will of the administration to support it. The program longevity of the sample group ranged from 0 to 28 years. The shortest was 0 years or just a few months. The mean length of program was 11 years. The median was ten years. Eighteen programs have run for more than ten years. Unfortunately, one of the longest running programs (20 y) was abandoned this year for lack of participation (Michigan State University).

These four parameters provide useful bases on which to judge the success of a CSS program. They could be used as metrics to gauge the success of programs. Participation rate could be measured by the number of visits to the web site and frequency of deliveries. However, factors such as physical size of the institution, number of staff available for the program, and the interest and support of the populace including the administration and the scientific departments play important roles in each of these parameters.

Figure 2 Example of CSS Program Website

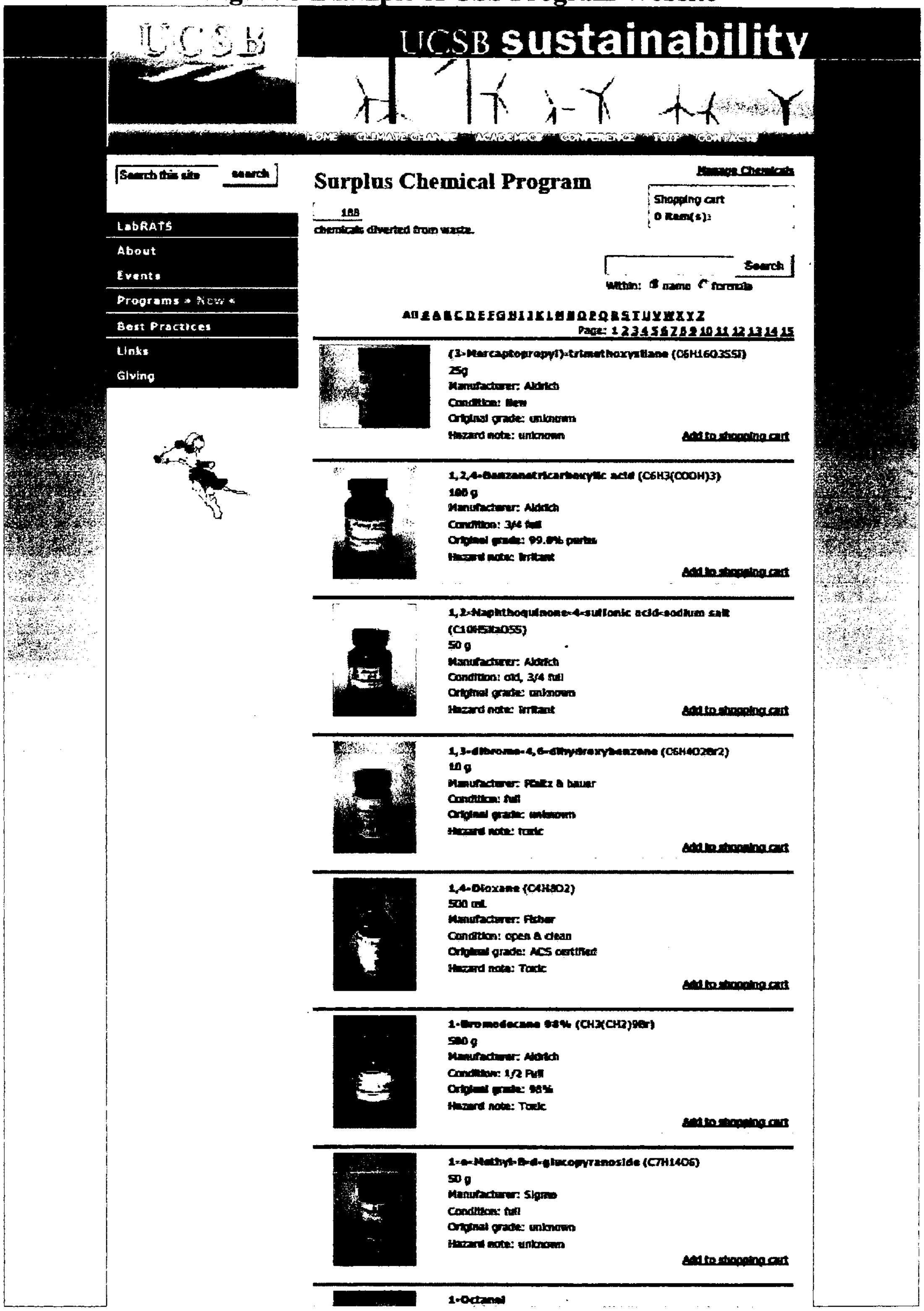
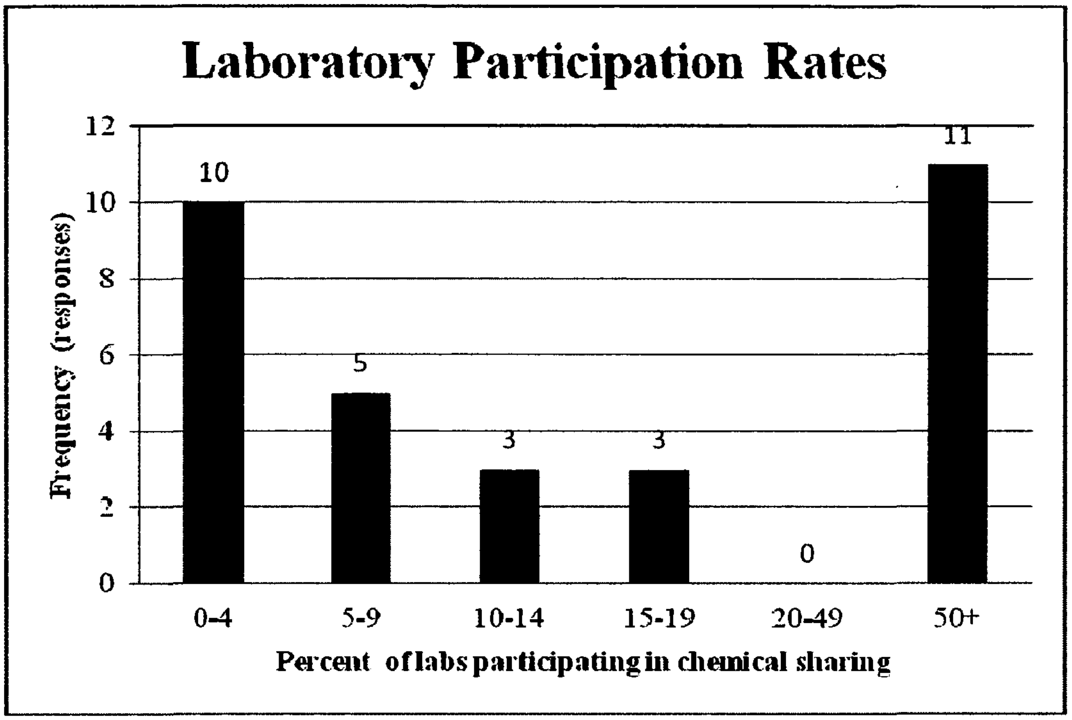


Figure 3 Participation Rates



In addition, the more control a university has over its inventory, the less surplus chemicals may be available for sharing (17). Control of chemical inventory would be a great improvement in the overall waste minimization effort.

Factors Affecting Success of CSS Programs

Now that the metrics which to evaluate the success of a CSS program have been found, what are the central elements crucial to a successful CSS program? These crucial elements will be discussed in this section.

Statistical analysis of program characteristics yields interesting information for this group of institutions.

The crucial elements of program success are those elements that make the programs function well and gain participation. This initial list of success factors was created from the open-ended question in the questionnaire asking the respondents to name the factors critical to the success of the program. Table 6 shows the factors that were named by respondents as the elements critical to the program success.

Table 6 CSS Success Factors
Ease of operation/maintenance free
No user charge
Proven product quality/knowing what people want
Personalized attention/fast turnaround
Continuous advertisement
User Enthusiasm/participation
24/7 access to website
Organization of the program/coordinate lab decommissioning
Cost savings (less hazardous waste)/compliance
Central control
Collaboration between chemistry and EHS

The importance of each these items was evaluated by the number of times survey respondents mentioned the factor.[3] The most common substantive answer (15%) was continuous advertisement. The next two most common answers are 24/7 access to the website and proven product quality/knowing what people want (12% each). The next most popular answer is no user charge (10%). Other issues such as connection with a chemical inventory program and monetary charges were not found to be as important in this question, even though they were mentioned in others.

[3] The number one answer to the question of what factors contribute to the programs' success was "na" or no answer (19%).

For the purposes of this investigation, the above top four characteristics were considered the crucial elements for successful CSS programs. These elements are discussed below and how these criteria rate among the respondents.

Marketing and Advertisement

14.5% of responses mentioned marketing and advertisement as critical elements for success and the lack thereof as a factor responsible for program failure. Marketing is accomplished in several ways. Some examples that were mentioned are:

- Email blasts alerting people to new surplus chemicals that have become available.
- Flyers announcing an "open house" in a laboratory recently abandoned where chemicals left can be adopted.
- Innovative websites where researchers can see the surplus chemicals available.
- Training new graduate students.

Marketing and advertisement are essential to attracting interested participants, to create a "buzz" around sustainability, and to connect initial information about surplus sharing provided in training with actual opportunities to obtain free chemicals. Advertisements increase student involvement by promoting the program. Respondents reported that every time the program is publicized, they get increased hits on the website and more requests for chemicals (18). The goals of improved marketing include involvement of research and teaching groups, having labs use surplus as first choice and gaining trust of customers so they will participate.

An example of an innovative advertisement is included in Figure 4.

24/7 access to the website

An initial question as to whether the institution used a website to list the surplus found that 23 of 32 (72%) considered a website to be an essential tool for alerting potential users about the inventory of available chemicals. Some websites were simple explanations of the program with lists of chemicals available. Many of the websites were secure and only available to university students and staff. Innovative websites were seen on several websites. These websites evoked a shopping website like Amazon.com complete with pictures of the chemical bottles, a search function, contact numbers and a shopping cart. An example of these websites was provided in Figure 2.

Knowing what people want/proven product quality

Most customers want quick turnaround and quality chemicals. This is the kind of service they get when they order new chemicals from commercial vendors. CSS programs must compete with these expectations. This element was mentioned by 12.5% of respondents. Some respondents mentioned that the ability to know what people want comes from communication from the good communication between EHS and the researchers. Proven product quality requires that the trained EHS staff screen the materials that come into the program to insure the integrity of the material for the second user. Screening the chemicals that come into the system was mentioned as an essential element of a good CSS program. Staff support and time available to provide trained chemical waste professionals to do on site review/ screening of potential surplus chemicals. It is important that the program become known as a resource for good cheap chemicals. Recipients of reagents should be confident of chemical quality and purity when accepting chemicals screened and logged by EHS. It is essential for the survival of the program to maintain a good inventory, there should be transparency about choices, (as exemplified by the websites in Figure 2 and 3) and listings should be kept up to date.

Monetary incentive /No User Charge

Most programs make the surplus chemicals available to second users at no charge to the adopter. A large majority (90 %) of respondents reported that the surplus chemicals were available at no charge to the second user. This could be an important characteristic of successful programs. It provides an incentive for people to reuse chemicals and it also is a reflection that charges for disposal are not the responsibility of the laboratory; rather they were reported to be the responsibility of the EHS department or the university administration. For the donor, the idea of disposal cost plays a small role if any in the decision to donate the chemical. For the adopter, the decision to use a free surplus chemical is independent of consideration of how much the chemical costs to dispose. He/she is much more likely to be aware of the cost to purchase the chemical from a vendor. Perhaps that information should be connected to the bottle, on the website.

Factors contributing to Lack of Success

Several questions in the questionnaire inquired about things that may contribute to the lack of successful CSS program. Four respondents in the study reported abandoned programs. Factors that respondents attributed to lack of success turn out to be inverses of the factors they associated with success. The main deterrents to a successful program involve inadequate transference of information. The following three items were the most frequently mentioned problems mentioned by the respondents as factors contributing to the failure or poor performance of the CSS program.

Lack of marketing

Marketing impacts interest level. Information about the existence of the program, the availability of the chemicals and the benefits of the program need to be communicated to potential users constantly. In fact, advertising/promotion/publicity and department involvement were mentioned by 12 respondents as factors critical to the functioning of the program.

Unwillingness to use old or suspect chemicals

This problem was listed by seven respondents and has been heard anecdotally throughout this investigation. This problem relates back to the lack of quality control in the program and researcher biases against open bottles. Nonetheless, 22 respondents (71 %) reported sharing open bottles.

Lack of interest

A serious drawback to a successful CSS program is lack of interest among potential users of the free surplus chemicals. Six respondents mentioned this. This is related to the lack of marketing. Some respondents mentioned that changing the culture and improving the participation rate was an important way to improve the CSS program. This was also mentioned in Reinhardt et al. (1996).

One respondent said that the low inventory of surplus chemicals was a good sign because it meant that researchers were being more careful not to order too much and that communication between labs had improved and more informal sharing had begun to take place. (19)

Lack of administrative support

More labs require more administrative support, although within public institutions in this sample, the level of support was independent of program longevity. Within the private institutions in the study, administrative support was associated with a longer running program (5.5 years without support and 9.25 years with support). Holding constant the number of labs, the public CSS programs have been around significantly longer than private programs by an average of 12.8 years vs. 7 years. Campuses with more labs were associated with longer running programs. These tended to be the public schools in this sample. These data show that there may be a scale effect – e.g., CSS programs may be more viable in university settings with more labs. There of course may be a limit to the scale effect. Too many labs may make it difficult to manage chemical purchase and use.

Recommendations

CSS Programs reduce chemical waste streams and save money. Chemical use is essential to the operations of many laboratories on campuses, making chemicals an important resource to protect and maintain properly. Recipients of reagents should be confident of chemical quality and purity when accepting chemicals screened and logged by EHS. By using surplus reagents, secondary users will avert significant energy consumption and greenhouse gas emissions from chemical manufacturing. Programs lacking these features will have a difficult time being successful.

Figure 5 is an example of an advertisement created by one university in the study to advertise their CSS program.

How to make a good CSS program – Recommendations from the respondents

The final question on the questionnaire was "What advice would you give to schools that are considering starting up a surplus sharing program?" This section reflects the ideas that were collected in the previous sections and summarize them . If someone were considering starting a CSS program, these are the important considerations that practitioners in the field suggest. The advice falls into five areas, storage, oversight/management, communication, customer service and inventory. Their comments are summarized next.

The four most significant aspects named by respondents as crucial to a successful CSS program were identified based on frequency of responses. They are: 1. storage space for the surplus chemicals, 2. policies for accepting and keeping the surplus, 3. innovative communication methods, and 4. dedicated, knowledgeable staff.

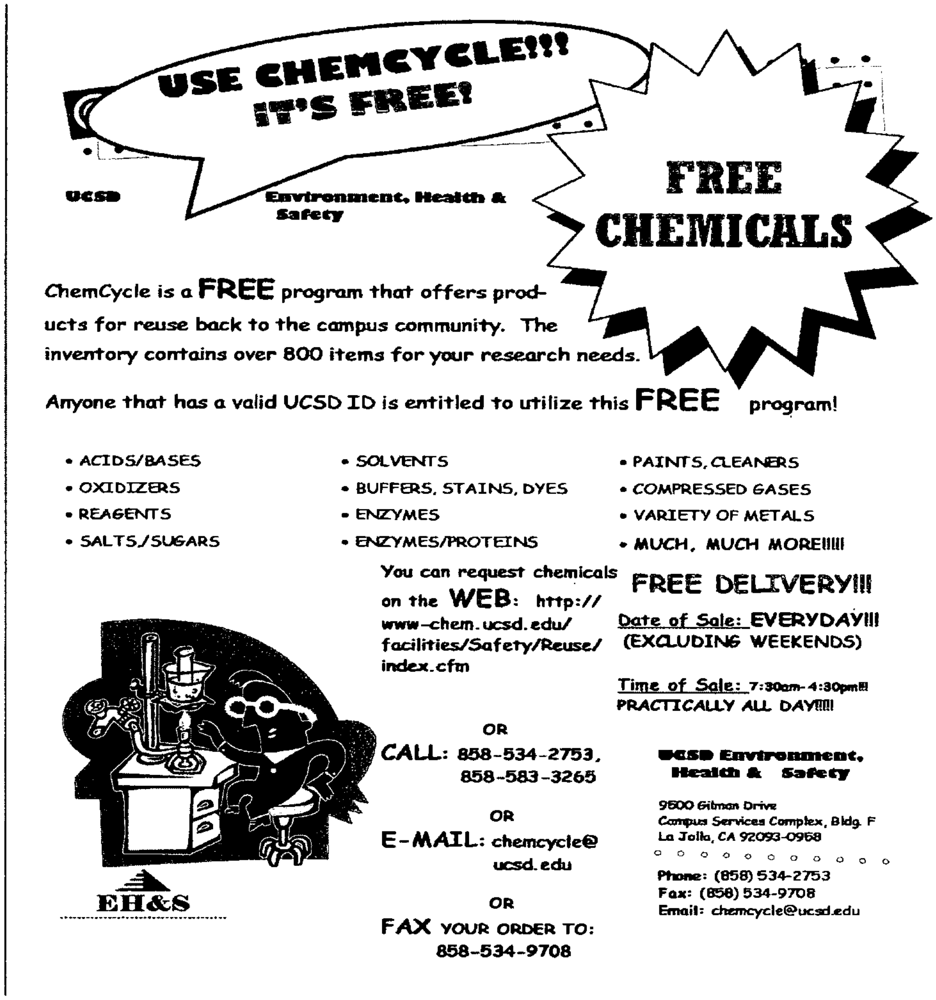
1. **Storage.** Four responders stressed that proper storage is important to have in a good separate, secure location and that a department has to have proper storage space for the compounds they are going to offer and enough room to organize the storage of surplus chemical inventory.

2. **Oversight/ Management.** Many responders mentioned the important of good management of the program. They wrote that CSS programs can get out of hand and become a liability if not managed properly. They recommended following a simple model that is easy to implement. They stressed the importance of having someone with a good chemistry background to manage the CSS program. A well-

trained chemist can properly identify and interact with lab groups to encourage participation. Management of the program includes making rules for inclusion or chemicals and that not all chemicals should be exchanged. Put limits on what can go into the exchange over time to reduce the efforts of managing undesirable chemicals in order to prevent hoarding of chemicals. They wrote that it was important to have a good waste program first and that the CSS program should coordinate with the hazardous waste program and the lab safety committee. Note that this is different from administrative or department support which seems less important in many settings.

3. **Communication.** Many respondents stressed that good communication is essential to convey what is available to potential customers. They wrote that information about available chemicals and about the program's advantages (e.g., FREE CHEMICALS) on should be conveyed a regular basis. An online website with pictures is important. It shows customers what they are getting. Develop a good marketing strategy and "advertise, advertise, and advertise!" Advertise regularly about the advantages of sharing items in the exchange in multiple ways. Automate notifications to people that have items in the exchange.

Figure 4 CSS Program Flier



4. **Customer Service.** Many respondents wrote about customer service. They advocated getting to know what customers want: what chemicals certain labs use and when that item arrives in the inventory. Be proactive and contact lab groups to see if they have interest in obtaining the chemical. Get buy in from the users before starting the program. Don't keep something that they don't plan to use. Know who your stakeholders are and maintain the program only if your cost-benefit analysis is in your favor. Understand that there are barriers to use of used or "possibly impure" chemicals by researchers. Running a chemical recycling

program can be time consuming and result in only minor measurable gains. Prompt delivery is important to insure some sense of reliability.

5. **Inventory.** Many respondents thought that an inventory program was an important tool for keeping track of surplus chemicals. They advised developing a simple database to track chemical inventory or work with a good working inventory locating system, user friendly website and forms. Work at having a policy of checking surplus inventory prior to making chemical purchases. Consider specific chemical needs first and then identify waste streams that might be able to meet them. Make sure to keep track of who owns the chemicals and share that information with other interested parties. Look at reducing or eliminating initial commercial purchase with better inventory controls.

Rules for inclusion in the surplus inventory

Some of the responses in the last section of the questionnaire invoked the importance of ensuring that the surplus chemicals are ones that second users would need. The respondents stressed that in order for surplus chemicals to be useful to other users that program managers, they should be discriminate about the chemicals that come into the program and that chemicals included in surplus should be ones that are in demand with packaging that is in good shape clearly labeled. Thus CSS programs typically involve rules about donations and types of chemicals that will be accepted.

Here are some typical rules that are instituted.[4]

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[4] Source: University of Washington, University of North Carolina, University of Oregon.

- Only accept chemicals in excellent condition, not past their expiration date, and preferably unopened. Original labels must be intact. Lids must not show signs of leakage.
- When exchanging chemicals, the chemical owner should make sure that the recipient is a University employee who has a reasonable use for the chemical.
- If the university has an inventory program, the former owner should remove the chemical from their inventory. The new owner should add the chemical to their inventory.

The exchange of cyanide and arsenic compounds is restricted. The exchange of radioactive material, Drug Enforcement Agency (DEA) controlled substances or biohazardous material is prohibited.[5] This prohibited list also includes radioisotopes, and explosives (Bowling Green State University, University of Washington, University of California, San Diego).

Impediments to creating a successful CSS program

To add to the recommendations of the respondents, ideas for combating additional issues that arise as obstacles to CSS. These issues and ideas came from the surveys and interviews with the respondents.

Reuse of Chemicals purchased with Grant Money.

Questions have arisen as to whether chemicals that were purchased with grant money should be reused by others not involved with the grant. However, the alternatives are illogical. They are: 1. To keep the unused chemical on the researcher's shelf until the

[5] Excerpted from University of Washington, UNC, UO.

project is over, they clean off the shelf and it is disposed, or it expires and it is disposed or, 2. the researcher leaves the university and the lab is cleaned out or, 3. dispose of the chemical (sometimes without opening the bottle). This is not the intention of the grant funding and that efficient use and sensible chemical ordering would be better and a less wasteful practice. However, the university can take action through CSS or careful inventory management to lower the costs of hazardous waste disposal.

Hoarding

Another issue related to the availability of free chemicals is hoarding. Some researchers cannot resist a bargain and will adopt a chemical even if they don't really need it, but because they might need it someday or because it would look good in their collection. The idea behind chemical surplus sharing is to make distribution of chemicals more efficient. One way to avoid hoarding would be to identify and include only what is proven to be really reusable. This can be accomplished by carefully screening what is included as surplus, with potential users in mind. This was recommended by several respondents.

Reuse of open chemical bottles

Some researchers do not want to use a chemical that has been opened for fear of it being tainted by a previous user. A solution to this would be to improve screening of chemicals that are to be included in the surplus program and to improve transparency so that potential users could see the collection (on line or in a storage room). Potential users could gain confidence in the quality of the surplus chemicals if they are initially screened by EHS for inclusion. Rules prescribing the quality of chemicals to be included in surplus collection would also help this. This improvement would gain the trust of customers so that they would be willing to participate.

Lack of Interest

Lack of interest was identified as an impediment to a successful CSS program. To generate interest, public relations work could be done to get administration, departments and labs on board with the program. Training of new graduate students could include information about the CSS program. Safety committee meetings could include information about the program and if possible, reporting of metrics – e.g., dollars saved, bottles shared.

Conclusion

Many research laboratories use hazardous chemicals to carry out their research. Hazardous chemicals, if improperly handled can cause pollution and present risks to health safety and the environment (Creighton, 1998). The improper use and disposal of chemicals may impact the university community and the surrounding community. CSS programs can help to reduce hazardous waste. CSS programs have great promise for intercepting excess chemicals from laboratory waste streams.

Many universities have tried and are currently carrying out CSS programs. These programs have potential to reduce the amount of chemicals purchased and later disposed of as hazardous waste. In this study, information from EHS personnel at 32 institutions of higher education where CSS programs have been tried was collected for this investigation. Respondents at many institutions considered their CSS programs successful. Information was collected on the workings of the CSS programs, on the on the elements that the respondents feel are responsible for the success of the program, and on the elements they see as barriers to successful programs.

DISCUSSION

A CSS program can be a successful method of waste minimization. By providing good service, good product good publicity and continual improvement of the program, the program will attract more clients and contribute to reducing the hazardous waste.

Key findings

Information/Communication as Key

Many respondents cite communication as being very important or critical to the success of a CSS program. Over 70% of the respondents listed communication as very important or critical to the success of the CSS program. Communication is very important but difficult do on an ongoing basis. Transmission of information is seen in several important facets of CSS programs. For example, keeping track of surplus chemicals in an inventory alone can facilitate surplus sharing and waste minimization if the information is made available to laboratory managers and staff who seek chemicals for the lab. Another case in point is the use of websites to publicize available surplus. Further examples are training about the program to new graduate students, and ongoing advertising and marketing of the program. Three of four success elements cited by respondents involve information transfer. Over 50% considered that the website is a critical element for success of the program. Keeping the online list up to date, continuous advertisement of the program and communicating with customers to know what they want and maintaining product quality. These are all important ingredients of a successful surplus sharing program. And, lack of marketing and advertisement is on the list of causes of program failure.

Criteria for successful programs

Based on the data collected, a typical successful CSS program should have continuous marketing and advertisement; a secure place to store and organize surplus chemicals, and good communication with customers that allows chemical managers to know what people want and to consistently provide quality chemicals. We can judge a successful program by participation rate, by money saved, by bottles kept out of the waste stream and by the longevity of the program. Simple surplus programs are easy to maintain along with general hazardous waste management.

Chemical surplus sharing goes hand in hand with a chemical inventory

An accurate inventory of chemicals and wastes in labs, departments and stockrooms is required by OSHA for safe and responsible management. An inventory can prevent over ordering and identify expired chemicals (1). Surplus chemicals can be designated as such in the inventory. Labeling the surplus on line and on the container helps to advertise its availability.

Hidden Secrets

Many institutions do not keep track of the bottles they are keeping out of the waste stream and the dollars they are saving. CSS is very appealing, particularly in the age of cost cutting and reduced budgets. A common attitude seems to be that the surplus program doesn't require any ongoing maintenance above what is generally required for the overall inventory system, so if it is used at all, then it can consider it a success. It is a good idea to keep track of financial savings because doing so might help justify the continuation of the program to the university administration or to point out the wasteful practices of the research labs.

Limitations of the Study

1. Non-random sample – purposive sampling – sought schools that had tried surplus sharing. The sample is most likely not representative of all the schools that have tried CSS. Statistics generated for the sample only apply to the group of schools in the sample.

2. Small sample size- 32 purposive samples. Results cannot be generalized. The schools in the sample may be representative of other schools but the results may not be generalizable.

3. This project is intended to be a qualitative study. However, certain respondents requested that their answers would remain anonymous so each set of responses was assigned a number. In that way the answers were not specifically associated in the analysts mind with a specific institution. That is the reason for doing the statistical analyses. Basic statistics were carried out on the sample. Generally means, medians, minima and maxima were calculated. In some cases statistics were used to look for relationships between different responses, associations and trends within the data.

Strengths of the study

This project is intended to be a qualitative study. The sampling effort attempted to find, though not a large random sample, a diverse sample with public and private, small, large, urban, non-urban, geographically distinct in order to understand CSS programs and issues associated with them.

Comparison with Previous Studies

Comparison with previous studies shows that the findings of this study are consistent with those in previous studies and that some that some innovations have been tried to overcome some obstacles since these articles were written. The findings of this investigation corroborate Reinhardt's 1996 observations regarding the importance of information transfer and communication (2). Leonard's finding regarding the lack of documentation of the recycled quantities and monetary savings were also found in some of the respondents today (7). Christiansen's finding that the most important factor contributing to the success of a CSS program is publicity was certainly echoed in the data collected for this investigation. He also stressed that the program should offer good service and good reliable product (8). This of course is still true today and a way to prevent abuse of the system. Each of these keys is an element of communication and exchange of information.

The experience of the New England Laboratories Project XL, found the biggest barrier to reuse of surplus chemicals was not regulatory, but cultural. They found significant resistance from laboratory workers to the idea of using chemicals that another lab has identified as waste (9). This idea was heard anecdotally during this investigation but seems to be combated by education and screening chemicals for inclusion in the surplus inventory and restricting them to good quality.

Amanda Ogden's finding about overcoming the cultural barriers of the laboratory community (10). High turnover of the graduate student population and decentralization of the science departments is a common phenomenon on many college campuses. As reported by Shriberg (11) Monteith and Sabatini (1997) found that people were supportive of sustainability mantra but when implications became apparent, disparities in approach were found.

A follow up to Ogden's thesis work focused on upgrades to the CSS program to increase the amount of chemical tracking of chemicals on campus. A review of the system in 2006 cited one reason for the success of the program was the integration of the chemical exchange feature with chemical inventory management (20). Changing organizational and human behavior is the key and setting goals, measuring progress toward those goals and ensuring transparency of this process can achieve this. In this study chemical inventory tracking was also found to be an important partner to CSS.

Future research needs

An attempt was made to find participants through CSHEMA. But only nine respondents were obtained in this manner. To get a more representative picture of the state of chemical surplus sharing in the US, a larger swath of the university population should be contacted. However, Michael Cimis, in his study of Environmental and Chemical Management in Higher Education sent 150 surveys out and received 31 responses (21).

Conclusions

The Value of CSS Programs

Chemical surplus sharing is one aspect of the goal of a sustainable campus. According to the data collected for this investigation, most chemical purchases are by individual researchers, over the internet. This uncoordinated action by individuals alone creates chemical surplus. Some measure of chemical surplus arises when there is little or no control of chemical purchases and little or no oversight or coordination among laboratories. This type of control could make a great difference towards waste minimization. Since this coordination and control is not a reality in many places, CSS programs are another measure that could be taken to reduce chemical waste produced by the laboratories. A comprehensive inventory that is available to all laboratories and some control over chemical purchases could reduce the need for a formal surplus sharing program. Steve Brehio of Northeastern University put it well: "A surplus sharing program is good to have but software to manage a centralized inventory that researchers can access would further enhance recycling and avoid many unnecessary purchases". (19) This is true. Thirty respondents in this study reported having some type of inventory. If this tool was used to manage purchases, many chemical surplus programs could become informal.

Successful programs

Based on the data collected, a typical successful CSS program has continuous marketing and advertisement; a helpful up to date website with pictures and descriptions of chemicals available that is available 24/7; a secure place to store and organize surplus chemicals, and good communication with customers that allows chemical managers to know what people want and to consistently provide quality chemicals. A successful program can be judged by participation rate, by money saved, by bottles kept out of the waste stream and by the longevity of the program. Simple surplus programs are easy to maintain along with general hazardous waste management.

Information/Communication as Key

An important finding of this investigation of the CSS program experience of 32 institutions is that an important component in CSS programs is transmission of information. Transmission of information is seen in several important facets of CSS programs. An illustration of this is that keeping track of surplus chemicals in an inventory alone can facilitate surplus sharing and waste minimization if the information is made available to laboratory managers and staff who seek chemicals for the lab. Another case in point is the use of websites to publicize available surplus. Further examples are training about the program to new graduate students, and ongoing advertising and marketing of the program. These are all important ingredients of a successful surplus sharing program. And, lack of marketing and advertisement is on the list of causes of program failure.

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CHAPTER II

USING TRANSPARENCY TO INCREASE AWARENESS OF CHEMICAL HAZARDS

INTRODUCTION

Many systems and campaigns (1) have been developed in recent years to provide workers or communities information regarding toxicity and exposures to toxic chemicals (2-7). Examples of this are the USEPA's Integrated Risk Information System (IRIS) (4, 8), Environmental Working Group (EWG)'s Chem Index and the Agency for Toxic Substances and Disease Registry (ATSDR)'s Tox FAQs (4, 9). The objective of these programs is straightforward: to provide non-technical laypersons and workers in technical jobs and communities with information about chemicals, so that they will be able to make better choices in employment, work practices and their personal lives. The "Right-To-Know" has become a rallying point for organizing stakeholder groups around chemical health and safety issues (10). Health and safety practitioners and advocates hope that by improving access to chemical information for workers and community members, companies might be pushed to change their chemical practices such as improved chemical labeling, improved Material Safety Data Sheets (MSDS), and reduced use of toxic chemicals and greater chemical protection for workers. Internationally, the European Union Registration, Evaluation, Authorization and Restriction of Chemical Substances (REACH) Regulations and Globally Harmonized System of Classification and Labeling of Chemicals (GHS) efforts are attempting the same thing (11). But transparency alone might not be enough.

Policy makers have employed transparency to communicate a range of public risks. Fung, Graham, and Weil (2007)(2) examined the effectiveness of a range of transparency policies—from school report cards and nutrition labels to corporate financial reports as well as developments in information and communication technology—by Google, Wikipedia, and others—foreshadowing a new generation of transparency policies.

A critical element for fashioning effective transparency policies is "embeddedness" which is the ability for information to be retained, absorbed, and integrated into one's consciousness and for that information to be assimilated and internalized (Fung, Graham, and Weil, p. 55). Supplying information is necessary but not sufficient to change behavior of those using it, but must become "embedded" in decision-making. Embedded information is actionable because it can be readily understood by users and potentially offers insights that can be acted upon in the course of decision-making. An assessment of the potential embeddedness of web-based chemical health and safety information is the basis of this research paper.

The mere provision of more transparent chemical information may not be adequate to provide more protection, or to change behavior of workers or employers. One problem is translating technical information into a form that can be understood for intended audiences. Another is tailoring the information so that it can be accessed for the most likely users. However, this misses the basic point - that, reliable or not, information not tailored to the appropriate audience will be of little use to them.

Technical information for non-scientists must be presented in a way that is useful and comprehensible to a lay audience. Information on health effects of occupational and environmental chemicals should be made available to workers, but research on chemical toxicity is often hard to translate. and, it is often unclear what readers can do with the information if they do understand it (2) (12, 13).

Existing sources of information are not always useful and understandable in providing intended users with the information they want in the form they can use. This investigation attempts to identify what would improve these information sources and to evaluate the characteristics of successful translation.

This study examines a form of transparency similar to public disclosure laws designed to benefit citizens by providing information on occupational and environmental hazards. Fung, Graham and Weil (2) have argued that there are three elements that determine whether a transparent message is "embedded" in the users' decision-making process: relevance, compatibility, and accessibility. In other words that information is in the right place, in the right format, and at the right time. The presence of these three elements increases the likelihood that information is understood and results in a desired change in behavior. Failure of an information source to achieve these elements will undermine its effectiveness at reducing risk exposure. As an expert in web usability has written: "If a web site is not easy to use, people simply leave. But if a camera is not easy to use, people will figure it out because they hold a physical object in their hand that they've invested in" (12).

In order to study the embeddedness of websites that provide chemical health and safety information, this investigation examined the characteristics of useful web-based tools by evaluating the sites' relevance, compatibility and accessibility for subjects for whom chemical exposures may occur on a regular basis. The goal of this study was to investigate how the three characteristics of embeddedness influence preferences of web-based information and how these preferences then affected future behavior. An additional goal was to assess whether there were differences between workers and students in website preferences and behavior.

To investigate these questions, several existing websites with chemical health and safety data, available to anyone with access to a computer and the internet were evaluated as sources of chemical information for students and employees at Harvard University and University of Massachusetts Lowell. Subjects of the simulation were asked to assess the hazards of two different common chemicals typically found in university laboratories. Based on their experience in the simulation, the websites were evaluated based on measures of their relevance, compatibility and accessibility. The subjects of the study graded the websites' performance as sources of right-to-know information based on detailed measures of these criteria. They then provided information on the likelihood that they would use the sites in the future based on their experience in the simulation.

Goals of the Research

The purpose of this research was to explore the concept of embeddedness in the context of chemical health and safety in university laboratories. As stated above, embeddedness is the ability for information to be retained, absorbed, and integrated into one's consciousness and for that information to be assimilated and internalized. When information is "embedded", it is integrated into user decision-making and can cause a change in behavior.

A set of exercises was designed and participants recruited to assess the following principal goals:

1. To explore the role that embeddedness plays in establishing website preferences in participants seeking chemical health and safety information.

2. To explore whether website preferences identified predict future behavior.

3. To determine whether there are differences between students and workers in website preferences and predictions of future behavior.

METHODS/INVESTIGATION – BACKGROUND

There are many potential sources for information about health and safety risks commonly found in academic laboratories. This type of information can be found in National Institute for Occupational Safety and Health (NIOSH) databases, such as the abbreviated versions found in resources like the NIOSH Pocket Guide to Chemical Hazards. The pocket guide is intended as a source of general hygiene information for workers, employers, and occupational health professionals. Material Safety Data Sheets (MSDS) are also a source of this information.

However, the existence of these sources of information does not necessarily mean that lab workers or students will use it. One must have a Pocket Guide on hand and be able to interpret the information within it to be able to use it. Similarly, MSDS's may not contain useful or accurate information (13) and they are not always available at the time they are needed. And neither resource is available in languages that are understood by many graduate students who come from other countries. Students and workers in the laboratory and employees from non-English or non-Spanish speaking backgrounds may not have ready access to translated resources. However, there are numerous alternative resources on the internet that supply this information for non-English speakers, on the United States Environmental Protection Agency (EPA) website, on websites of non-governmental organizations and there is always Google.[1]

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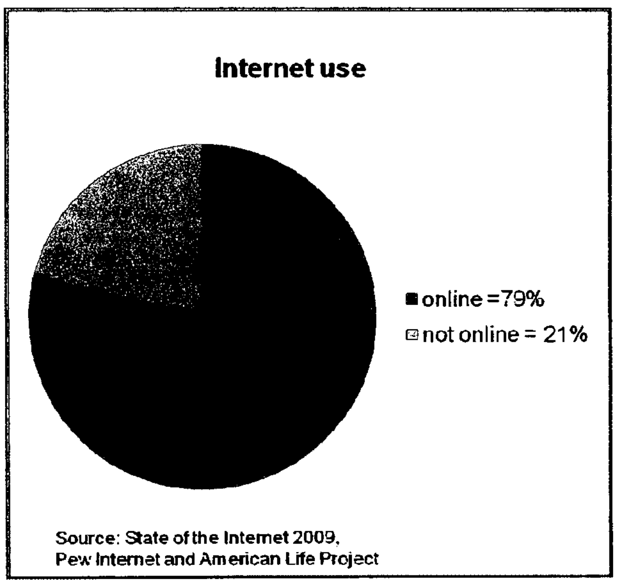
[1] Google Inc. is an American multinational internet corporation invested in internet search and other ventures. According to market research published by comScore in November 2009, Google is the dominant search engine in the United States market.

Web-based resources are available to provide health and safety information to potentially solve the problems described above. This investigation assessed the success of seven of these websites as sources of chemical health and safety information that students and workers might be exposed to in academic laboratories. To investigate this issue, hypothetical questions regarding two chemicals (ethylene glycol and acetonitrile) were constructed and participants were asked to research the questions using these websites and then to evaluate the sources of information. The technical information that the participants sought in this investigation was chemical health and safety information; information about health effects, and potential exposures associated with typical chemicals found in academic laboratories.

How People Obtain Information

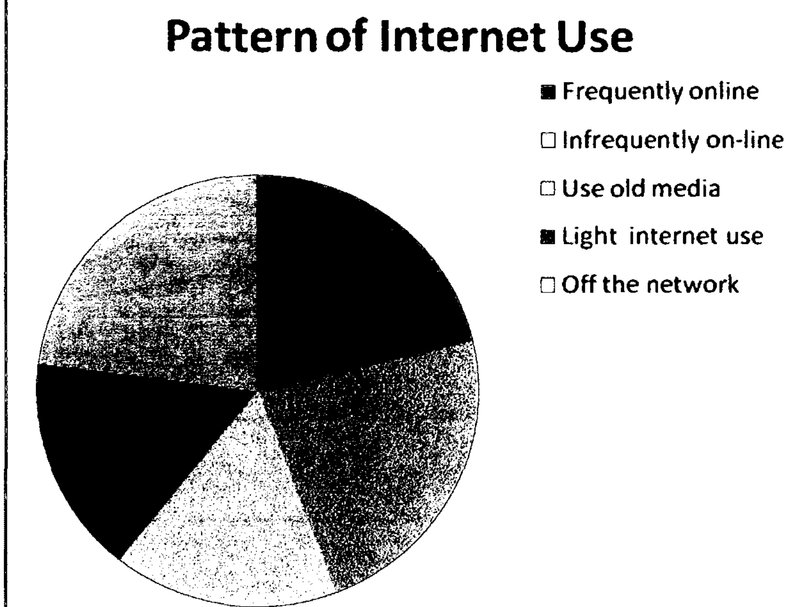
The Internet may be the best place for chemical health and safety information to be located and increasingly it is the major source many types of information. A study by the Pew Foundation on Internet use found that the Internet plays a significant role in how people seek information. Seventy-nine percent of the American adult population use the Internet (14, 15). Eight in ten people in the Pew study have sought health information on line. A large percentage of these are working age. According to the Pew study, Generation X (age 33 to 44) is the most likely group to bank, shop, and look for health information online (14). Many of these users say the internet has had a significant impact on the way they care for themselves or for others (14). Increasingly, people who lack access to the Internet will be less able to keep up as more information and services are made available exclusively on line (16). At the time of this writing, approximately 21% of US adults do not use the Internet or only have dial-up (slow) connections, making efficient use difficult. These people are considered to have "low access" (17). Figure 5 illustrates these percentages. People with low access to the internet may face health problems at the same rate or higher than those who have higher rates of Internet use. In fact, according to the Pew study this low access group is older, poorer and less well-educated than the general population (1). In the Pew studies, people overall gave the Internet higher marks than any other source of information when they were looking for information to solve problems (16).

Figure 5 Internet Use



The Pew Internet studies have found that the Internet can play a large role in how people seek information (16). Figure 6 shows the pattern of internet use.

Figure 6 Pattern of Internet Use



Source: State of the Internet 2009, Pew Internet and American Life Project

Effectiveness of the Message

Given this increasing movement towards seeking problem solving information on the internet, there is also a growing need for guiding principles for providing this information. Many researchers, organizations, and website developers are exploring alternative ways of helping people to find and use high quality information available on the internet. Public health researchers such as Gagliardi and Jaddad have attempted to do this in a 1998 study (updated in 2002) where they examined instruments used to rate the quality of health information on the internet. However, they found that many incompletely developed rating instruments continued to appear on websites providing health information, even when the sponsor organizations no longer existed (18, 19). Occupational Safety and Health professionals also have tackled this subject (20). Government agencies such as the National Library of Medicine (NLM), and the New

Jersey Department of Health and Senior Services (NJHHS), and non-profit organizations such as the Collaborative on Health and the Environment (CHE), and Environmental Working Group (EWG) provide websites that attempt to provide answers to questions about the use and toxicity of chemicals (4, 21, 22).

Guidelines are especially necessary for translating technical information, such as the toxic effects of chemicals for general audiences or non-technically trained workers in a scientific laboratory. Research in the field of advertising and public policy has addressed this issue and identified the characteristics that constitute an effective source and accessible arrangement of the data (12, 17, 23).

Health and safety information on the internet falls under risk communication. Research into risk communication for workers (20) has been conducted since the 1986 advent of the Occupational Safety and Health Administration's (OSHA) Hazard Communication Standard (29 CFR Part 1910.1200). However, as the use of the internet rises, the "net" has gained greater and greater importance as a source of health information, tools have been developed to rate the quality of health information on the internet (18, 24, 25). Some studies have also examined the usefulness of safety information. The research in these areas has contributed to improvements in the effectiveness of the internet as a source of health and safety information.

Embeddedness

The concept of "embeddedness", adapted from Fung, Graham and Weil (2007), is a critical element for fashioning effective transparency policies and is the basis for this investigation. This concept describes whether the information provided by disclosure is retained, absorbed, and integrated into the intended user's understanding of decisions they face. When information is "embedded", it is integrated into decision-making and can result in a change in behavior. Evidence of the connection between information disclosure and behavior change through the mechanisms of embeddedness has been documented in a diverse set of transparency policies (2, 26). Fung, Graham and Weil (2) argued that there are three elements that determine whether a message is "embedded" in the users' decision-making process. The three elements relevance, compatibility and accessibility are discussed below:

Relevance

Relevance relates to the pertinence of the information to user decisions. Three specific components of relevance are: a. Motivation, b. Culture, and c. Context. In terms of motivation, a worker who is worried about health effects he is experiencing may be highly motivated to find out what might be causing these effects. Motivation for that individual is likely affected by his or her current health condition. For students in laboratory sciences, reasons for caution about chemicals used in the lab may not be clearly perceived because of optimism biases related to current health status. The culture of the laboratory environment influences attitudes towards health and safety practice (27) and often requires quick access and little time for consideration of uncertainties. Finally, for the intended users, the context of the information is important. Web-based information must be put in context so that it can used by its intended audience in a meaningful way – and in a way that makes sense in terms of their daily lives and needs; and in a way that provides immediate feedback.

Motivation

People interested in disease symptoms may try to find chemicals associated with those diseases. They may be curious about the health effects of a chemical that appears on a label. It is critical to determine what prompts or triggers people to search for health information and to fashion the information with this in mind. This involves use of common terms and consideration of the audience that will use the information. It is important to consider whether the person can choose which chemicals to use and is looking for less toxic alternatives. An optimistic bias2 may also play a role here both because of a false sense of control of hazards and, in the case of students, a sense of invulnerability that comes with youth (28, 29). Research to understand what prompts people to search for information and what is truly relevant to the target audience is critical.

Culture

The academic research laboratory environment is not usually conducive to conducting extensive research into the care and handling of laboratory chemicals. There is often a tension between "onerous" safety rules that are perceived to interfere and the conduct of research. A critical factor impacting the lab culture might be the lack of disclosures about previous problems encountered by others attempting procedures in the lab. Students

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[2] Optimism bias is the demonstrated systematic tendency for people to be overly optimistic about the outcome of planned actions.

attempting to conduct experiments are dependent on colleagues, MSDS and quick Google searches to find information on toxicity, on personal protection equipment needed and on chemical handling. The norm for this situation is, a "quick and dirty" search for information.

Context

When laboratory personnel access information about the chemicals they work with, long lists of chemicals are rarely useful. Instead – information needs to be presented in a way that provides relevant information about potential exposure pathways and tasks required in the lab that might cause exposures to that chemical. MSDS are examples of information sources that are readily available but marginally useful. They are rarely useful to the audiences that could use them (30) because MSDS information can often be vague, non-specific and inadequate (13).

Compatibility

Information must be compatible with the user's language and 'socioeconomic' culture. Compatibility is comprised of three important elements – language, formatting and comprehension (31).

Language

The information must be in a language and at a literacy level that is understood by the user. Not everyone speaks or understands English, yet much of the labeling and chemical information available in the laboratory is in English. In addition, technical jargon in information files may dissuade people from seeking information.

Format

Information needs to be in a format that is 'user-friendly' (12, 13). For example, technical presentations are often filled with graphs and tables. But, when writing about something concrete like a proposed landfill, it may be better to provide an actual picture of what the landfill will look like to convey appropriate information. Too often, MSDS are written in terms that are vague, not universally understood, and without concern for the people who need them.

Comprehension

When information is consistent with a person's language and socio-culture economic culture, it increases the likelihood of it being understood. But these are not the only ingredients to comprehension. Providing comprehension may also mean avoiding abstract language, and using pictures to display concepts.

Accessibility

Information must be in a place that the user can easily find it and it must be consistent with the conventional patterns for finding information. It is also critical that the data are available quickly, when one needs to make decisions. Four important elements of accessibility are: 1. Speed of search, 2. Search engine optimization (SEO), 3. Search algorithms, and 4. Points of capture. All of these elements are important to conducting searches for information on the internet. The last two elements are important for finding information on websites.

Speed

The amount of time expended to gather information is an important determinant of whether it will be used. The quicker that information can be accessed, the greater is accessibility to users. This has become an important dimension of web search generally. The speed of capture is the reason that the internet is an attractive resource for seeking information. Quick responses are a hallmark of Google searches and have been since Google's introduction in 1997 (32). Expectations for speedy searches were raised by the Google Search Engine (33).Google raised the expectation bar for speed for all searches with the effect that the default search method for many people is "to Google it". And if that status was not enough, Google recently unveiled a new search feature called Instant Pages that will give users even quicker connections to websites from links on query results (34).

Search Engine Optimization (SEO)

SEO is the process of improving the visibility of a website or a web page in a search engine search results. In general, the earlier (or higher on the page), and more frequently a site appears in the search results list, the more visitors it will receive from the search engine's users (33). SEO may target different kinds of searches, including images, local searches, videos, academic articles, news and industry-specific search engines (35). SEO gives a website prominent presence on the web.

SEO has become a critical element in internet marketing strategy. Designers of websites practice SEO. When implementing SEO, website designers consider how search engines work, what people search for, the actual search terms typed into search engines and which search engines are preferred by their targeted audience. They may optimize a website by editing its content and programming language and associated coding to both increase its relevance to specific keywords and to remove barriers to the indexing activities of search engines. Promoting a site to increase the number of inbound links is another SEO tactic, done by making efforts to rank well in their search engines. Some designers even manipulate their rankings in search results by stuffing pages with excessive or irrelevant keywords. For information seekers, this adds to the "noise" obtained in internet searches because these tactics can influence which sites appear higher on a Google search list. This is currently a problem that makes it difficult to obtain reliable results quickly but one that Google and other search engines work to prevent (33).

Search Algorithms

Another related design element of accessibility reflects the use of algorithms by search engines to conduct searches. The leading search engines, such as Google and Yahoo!, use crawlers to find pages for their algorithmic search results. A web crawler is a computer program that browses the internet in a methodical, automated manner. Search engine crawlers may look at a number of different factors when crawling a site but not every page is indexed by them. Distance of pages from the root directory of a site may be a factor in whether or not pages get crawled (36). Additionally, search engines sometimes have problems with crawling sites with certain kinds of graphic content, flash files, portable document format files such as zip files, and other dynamic content (37). These design elements may be critical to the accessibility of a website and determine whether a web site is easily accessed. Understanding search algorithms is critical to website accessibility.

Points of Capture

Websites have different points of information capture or ways for users to find the information they are looking for. These are virtual handles for users to latch onto. The most accessible sources of chemical information have multiple points of access such as using a Chemical Abstract System (CAS) number, searching alphabetically by chemical name, searching by disease, or by chemical formula.

The participants in this exercise were asked in the first stage, to conduct a Google search. In this portion of the exercise, all of the accessibility elements were important. In the later portions of the exercise, the website locations were given to the participants so they did not have to search for them. In these portions of the exercise, the accessibility of information on the website was important. Therefore, statements presented to participants to gauge the accessibility of the websites pertained to arrangement of the information on the websites. The following statements were presented to the participants to gauge the accessibility of the websites.

Representativeness, compatibility and accessibility are three critical criteria for creating embedded information; information that sticks with a person and that make a difference.

METHODOLOGY

A multi-method study was conducted using interviews, hypothetical problem sets and observations to document participants' experience with and reactions to chemical health and safety information presented on several different websites and to determine the embeddedness of the information found in those websites. This study focused on people who come into contact with chemicals in the workplace; both technically trained and non-technically trained personnel at two major research universities in New England (Harvard University and University of Massachusetts Lowell). There were two participant groups - employees and students.

This study had three components, each addressing aspects of embeddedness: 1. Evaluation of users' experience with seven websites through site evaluation and ranking. 2. Evaluation of the impression of the websites that participants came away with through interviews about the sites and potential for revisiting and; 3. Observations of how they conducted the search.

The procedures followed to recruit participants, compose the exercises and carry out the experiment are described here.

Recruitment of Participants

Two small test groups (approximately 18 participants in each group) were chosen to evaluate the usability and success of certain websites as sources of health and safety information. The participants were chosen because their jobs or student's course of study require them to handle chemicals in the laboratory. The first group of participants chosen was comprised of employees at the universities that bring them into contact with laboratory chemicals. The group was composed of laboratory managers and lab technicians in science departments. The second test group consisted of science undergraduate and graduate students at the universities. The recruitment questions are presented in Appendix A.

Participants in groups were recruited through several means including university science safety committees, email from a clerical and technical workers union, posted advertisements and emails from science department administrators requesting volunteers for help with PhD research. Attempts were made to recruit janitors through their union with little success. All participants recruited spoke English, although the researcher was prepared to translate the questions into the participant's language if necessary. The proposed method of choosing the participants was approved by the Harvard University and University of Massachusetts Lowell Institutional Review Boards.[3]

A recruitment letter was composed for both groups. When potential participants called or sent an email, a recruiting letter was sent to them. The letter enabled screening of the participants to identify people who could do the exercise. Questions about computer/internet use and chemical contact were used to identify people who used the internet and worked around chemicals. The recruiting letter is included as Appendix A. The recruitment letter was part of the pre-test described below.

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[3] **IRB #09-118-GEI-XPD**

Testing of Participants

A series of hypothetical questions was constructed and presented to the two groups of participants. The participants were asked to evaluate the sources of information based on the embeddedness criteria described above. The questions were hypothetical queries regarding chemicals that they may use or come in contact with and inquiries about health effects and potential exposures associated with chemicals. The same questions were employed for both groups.

The questionnaire given to both groups of people consisted of pre-test questions about their education, status as a student or employee and prior experience with internet searches and chemical health and safety questions. This preliminary exercise was followed by two hypothetical scenarios involving potential chemical exposures (of typical laboratory chemicals) in the laboratory. The first chemical used in the study was ethylene glycol. It was chosen from a list of typical chemicals found in the laboratory provided by several professionals in the Environmental Health and Safety (EHS) Department of Harvard University (38). Acetonitrile was also chosen for the study based on conversations with EHS professionals at Harvard University (38).

Both groups of participants were given the same hypothetical questions and asked to seek answers using Google and the six websites identified in Table 1. Following the hypothetical exercises, a series of post-test statements were posed about the search experience and opinions about the websites. The statements were based on the three criteria – Relevance, Compatibility and Accessibility. The participants were asked whether they agreed with the statements based on a five point scale. This was followed up with a post exercise interview.

Relevance Statements

The following statements were presented to the participants to gauge the relevance of the websites:

A. The information is relevant to you.
B. You can relate the information to your daily life.
C. It is clear what should be done with the information.
D. Information on the website is specific to the situation you are concerned about.

Compatibility Statements

The following statements were presented to the participants to gauge the compatibility of the websites.

E. The information on the website was compatible with your language and culture.
F. The information on the website made sense to you.
G. The language used on the website was clear and understandable.
H. Clear connections were made between the chemicals and health effects on the website.

Accessibility Statements

The following statements were presented to the participants to gauge the accessibility of the websites.

I. The information on the website was in a place that was easy to find.
J. The information was well-organized on the website.
K. The information on the website is arranged in a way that suits your needs.

Information Sources

Websites were chosen that are sources of information about chemical toxicity and chemical handling. The websites were identified through previous investigations by the author and through consultation with EHS professionals involved in chemical management. Criteria for inclusion included: 1. must be able to find information on BPA, acetonitrile or ethylene glycol. 2. Must contain searchable information on chemical health and safety. 3. Must have non-technical language. The seven websites chosen for use in this investigation are provided in Table 7 which presents a summary of website characteristics.

Table 7 Website Information

Website	**Agency Type**	**Year Started**	**Intended User Group**	**Information Provided**
Google Search	Google Publically owned corporation	1998	Everyone	Everything
ATSDR ToxFAQ	Government: Centers for Disease Control/Agency for Toxics and Disease Registry	By Congressiona l Mandate - 1993	Public Stakeholder s	Chemicals, Health Effects
EWG Chemical Index	Environmental Working Group - NGO Non- profit –Research Advocacy	1993	Public stakeholders	Articles on Topics related to health effects
CHE Toxicant and Disease Database	Collaborative on Health and Environment: NGO - Collaborative – Research Advocacy	2002	Public stakeholders	Information on toxics, exposures, and associated illnesses
New Jersey RTK Fact Sheets	State of New Jersey Department of Health and Senior Services	The NJ Worker and Community Right to Know Act Adopted 1984.	Community and Employees	Information on health hazards, exposure limits, personal protective equipment, proper handling, first aid, and emergency procedures for fires and spills.
NIOSH Tox Town	NIOSH – U.S. Government Agency	2003	High school and college students, educators, and the concerned public	Facts on everyday locations where toxic chemicals might be found Non-technical descriptions of chemicals Links to authoritative chemical information on the Internet Internet resources on environmental health topics.

International Chemical Safety Cards	International Govt. Agencies: International Programme on Chemical Safety: a joint activity of three cooperating International Organizations: namely the United Nations Environment Programme (UNEP), the International Labour Office (ILO), and the World Health Organization (WHO)	ILO C170 chemicals convention, 1990	Intended for use at the "shop floor" level by workers and employers in factories, agriculture, construction and other work places.	Over 1700 cards are available. Potential way of assisting to implement the Globally Harmonized System for the Labeling and Classification of Chemicals (the GHS).

Investigation Process/Participant Observation

The questions were carefully constructed and trial-tested on two recent college graduates and two custodians for timing and understanding prior to deployment on the participant groups. The investigation consisted of three stages. The stages are described below. All of the stages of the exercise could be completed on a computer with access to the internet. A copy of the questionnaire is included in Appendix B.

1. Pre-test

A pre-test was administered where basic information was collected about the participant including information about their access to the internet, their contact with chemicals, and the way the participant currently gathers information about risks plus several questions to assess their existing knowledge about a subset of chemicals. Questions relating to the pre-test were both in the recruiting questionnaire and the first portion of the exercise.

2. Use and evaluation of websites

The questions presented hypothetical situations involving handling of chemicals in the laboratory. Each participant was then given the same set of two hypothetical chemical risk questions. For each of the questions the participants were asked to use all of the seven websites, including Google to find useful information to find answers. They were asked to try the search using each website and rate the search experience of each one using the embeddedness criteria which were explained to them. Statements were provided in each criteria category that would help the participants rate the website. The questions are presented in Table 8. The following scale from one to five was provided to help the participants rate the websites.

1	Disagree strongly
2	Disagree
3	Neither agree nor disagree
4	Agree
5	Agree strongly

Table 8 Website Rating Questions		
Relevance	**Compatibility**	**Accessibility**
A. The information is relevant to you.	E. The information on the website was compatible with your language and culture.	I. The information on the website was in a place that was easy to find.
B. You can relate the information to your daily life.	F. The information on the website made sense to you.	J. The information was well-organized on the website.
C. It is clear what should be done with the information.	G. The language used on the website was clear and understandable.	K. The information on the website is arranged in a way that suits your needs.
D. Information on the website is specific to the situation you are concerned about.	H. Clear connections were made between the chemicals and health effects on the website.	

The participants were asked to keep track of their impressions of each website and to document them numerically in charts provided to the participants to complete. Based on the elements that characterize embeddedness, each of the participants was asked to evaluate the success of each website as a source of toxicity information. Each website was assessed by each participant for these elements. This exercise is similar to previous work done to rate health information on the internet (24, 25).

3. Post-test

Follow-up questions were composed to evaluate the participants' experience searching for the chemical risk information on the websites and whether the process and the information found will change the way they confront chemical hazards. The participants were asked to give overall ratings to the top websites in terms of the embeddedness criteria. They were asked to check off the sites they would revisit in the future and to document their choice for the most successful websites overall.

Data Analysis/Results

The following are the major goals of this inquiry:

1. **To explore the role that embeddedness plays in establishing website preferences for participants seeking chemical health and safety information.**
2. **To explore whether website preferences identified predict future behavior.**
3. **To determine whether there are differences between students and workers participants in website preferences and predictions of future behavior.**

These goals were addressed by pursuing the following specific questions:

1. Which websites do participants rate as most useful based on the embeddedness criteria of relevance, compatibility and accessibility?
2. Which websites do participants indicate they are most likely to return to?
3. How do participants' ratings of the sites, along the three dimensions of embeddedness, influence their potential for revisiting them?
4. Are the preferences of student participants different than those of employee participants?

Two types of data were collected during this investigation; surveys that were coded to create quantitative data, and text and interviews that were used for qualitative evaluation. This section includes analysis of both types of data.

Pre-test Questions

Data were collected from each participant on age, gender, education level, and years of work, job classification, and laboratory type. Pre-test questions were given to test the participants' *a priori* familiarity with chemicals. Pre-test questions also provided measures of internet search savvy and prior knowledge of sources chemical toxicity and safety. The answers to these questions in the pre-test portion of the exercise were compared to other questions answered after the session to see whether the participants gained anything from their exposure to the websites.

Fourteen questions were posed in the pre-test portion of the exercise to track the participants' a priori experience with chemical handling, familiarity with Material Safety Data Sheets, familiarity with typical laboratory chemicals, past searches for health and safety data, history of internet searching and past sources of chemical health and safety information. Statistics were used to determine whether any of the pre-test questions were correlated with website ratings.[4] To see if they would have any influence on the prediction of revisiting the sites, the top two pretest questions were tested for correlations with site ratings. The top two pretest variables identified from the exercise were: 1) prior knowledge of MSDS location and 2) previously sought health and safety information. It was determined that 2) sought health and safety information had a slightly higher impact when combined with ranking in predicting which sites would be revisited. Therefore, this question was included in the regression analysis.

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[4] STATA, a statistical package, was used to analyze data quantitatively.

Evaluation of Websites

Seven websites that present chemical health and safety data in formats that are theoretically aimed at lay people, were evaluated in this investigation. The participants evaluated the success of each website as a source of chemical health and safety information based on the criteria that determine embeddedness: relevance, compatibility and accessibility. Each website was evaluated with respect to the statements that were presented in Table 8 of the preceding section. This analysis evaluates the participants' ratings of the websites, projected future behavior and comparison between participant groups as to preferences and behavior.

Site Rating Scheme

To determine which of the websites were most useful in providing the necessary chemical health and safety information, participants were asked to rate the sites according to three criteria. As seen above in Table 8, within the three criteria there were several statements that were specific about their search experience. The participants were asked to fill out three tables (one for each criterion) for each of the two hypothetical potential chemical exposure situations described.[5] One chemical scenario involved ethylene glycol use in the lab. The second involved acetonitrile. Both of these chemicals are widely used in university laboratories. The ratings were on a scale from 1 to 5 as described previously.

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[5] A survey is provided as Appendix B.

The use of this numerical rating system enabled statistical analysis of the results. The ratings are discussed herein. The questionnaire used in this investigation provided information that could be coded into numeric measures, (following the methodology of Bloom and VanReenen (39). A numerical rating system using the website criteria was devised to assess the websites. All assessments were performed using the three criteria, Relevance, Compatibility and Accessibility ratings and other pre- and post test questions.

In this section, websites are discussed using the abbreviations used in the exercise to identify them. Table 9 provides a key to these abbreviations.

Table 9 Website Abbreviations

Website	**Abbreviation**
Agency for Toxic Substances and Disease Registry ToxFAQs	ATSDR
Collaborative for Health and the Environment	CHE
Environmental Working Group	EWG
Google	Google
New Jersey Right To Know	NJ
International Chemical Safety Cards	ICSC
National Library of Medicine Tox Town	NLM

Overall Website Preference Ratings

Websites were rated quantitatively using the scheme above and qualitatively in the study using interviews and certain questions on the questionnaires.

Post-Exercise Interviews

Post exercise interviews were conducted and recorded. The questions that were asked of each participant were:

a. Did exercise make sense to you; could you imagine yourself having similar questions that you might need to answer?

b. Which websites would you go back to and why?

Most of the participants who completed the exercise said that it made sense to them and that they could imagine having similar questions at times. The common situation that occurs in a lab is that when people need information about chemical health and safety, they often ask someone else in the lab, go to the MSDS or just Google the chemical name. "We aren't encouraged to spend hours researching chemicals. Most of the times you have do it as quickly as possible. Mostly you are lazy and you ask someone" (Participant 3 (40)).

Participants reported that MSDS are insufficient. Participants reported that MSDS do not often have the necessary information. They reported that "hazards are often unclear and I have a hard time differentiating between harmless substances and really toxic ones because of that" (Participant 2) (41). "MSDS are appropriate for the people who stock the chemicals and sometimes the information is very, very old. Often, many parts of the MSDS are left blank." (Participant 7) (42). "MSDS say hazards are unknown and have a hard time differentiating between harmless substances and really toxic ones. But they give you a sense like information about what kind of exposures to worry about. However, if I am going to be handling a chemical, I want to know about handling it. I am not worried about huge bulk quantities which are what the MSDS is usually about" (Participant 2) (41).

It was difficult for the participants to distinguish good resources from the search results and it took time to wade through them. A default shortcut strategy related by a participant is to choose government resources found on Google (43). This sentiment of uncertain reliability of results was reported by some of the participants. In general a web search starts with just Googling the chemical name. In a Google search, there is amazing speed (reported at the top of each search). But with Google there is also much noise. One participant commented, "You go to all sorts of websites that might have more useful information or might just be you know some kind of wacko being nervous about stuff that we use all the time well maybe they're right and maybe they're wrong but we're going to use that anyway. But we use it all the time and work on it keep using it all the time because that's how it works." (Participant 2 (41)). In other words, many times there is no way to judge the reliability of a site.

Quantitative Website Ratings

Ratings for the websites were generated from the participants' questionnaires. First the statements within a criterion were combined (averaged) to yield a criterion score (e.g., an overall "relevance" ranking for the information on ethylene glycol provided by the ATSDR site). The ratings were generated by averaging site ratings from the participants' exercises for the specific questions within a criterion category, creating an overall rating for each of the three embeddedness criteria based on all questions within that category. Based on the participants' responses, an investigation was conducted as to whether participants consistently ranked the site according to an embeddedness criterion to the different chemical scenarios—for example, whether they ranked ATSDR similarly in terms of relevance for both ethylene glycol and acetonitrile. The consistency in ranking was then tested using statistical analysis described below.

Overall ratings for each website from the two chemical scenarios are provided in Table 10. The results are listed for each of the two chemicals (ethylene glycol and acetonitrile) separately. For each chemical, the websites are listed in order of the highest rating for relevance for each of the two chemicals. It can be seen from the table that the ratings differed for each site and that the ratings varied between criteria and chemical scenario.

Table 10 Overall Website Rankings

Ethylene Glycol	**ATSDR**	**Google**	**NLM**	**ICSC**	**NJ**	**EWG**	**CHE**
Relevance	4.05	3.89	3.66	3.60	3.47	2.46	2.44
Compatibility	4.35	4.27	4.26	4.11	4.09	3.32	3.63
Accessibility	3.81	3.57	3.86	3.73	3.74	3.17	2.95
Acetonitrile	**ATSDR**	**Google**	**NLM**	**ICSC**	**NJ**	**EWG**	**CHE**
Relevance	3.14	3.73	2.69	3.68	3.91	2.41	2.35
Compatibility	4.02	4.17	4.10	3.70	4.32	3.26	3.08
Accessibility	3.47	3.72	3.70	3.16	3.91	2.63	2.46
Key :	1=Disagree strongly				n=35		
	2=Disagree						
	3=Neither agree nor disagree						
	4=Agree						
	5=Agree strongly						

The rating scale is listed at the bottom. ATSDR is rated highest for relevance and compatibility for the first question but NJ is the highest rated for the second question.

Several sites had compatibility ranging above 4 (out of a possible 5) for both questions. Only ATSDR has a relevance rating around 4 for either question. EWG and CHE have the lowest scores in both questions.

Table 11 tests whether embeddedness ratings for one chemical are correlated with those of the other chemical. The results indicate a positive correlation between participant rankings of one chemical with rankings of the same criteria of the other chemical, and 11 of the 21 correlations are statistically significant at a 0.10 level or above. Google, NJ and ICSC were significantly correlated within each criterion. Accessibility ratings were consistent for CHE and NLM. EWG relevance ratings were correlated and ATSDR ratings were not consistent. These results indicate that participants' opinions of the websites in terms of the criteria were consistent between chemicals. This meant that they understood and distinguished between the criteria.

In addition to trying to uncover relationships within the criteria across chemicals, whether participants distinguished between websites by rating websites differently based on the information they provide was investigated. To do this, paired t-tests were performed to investigate the relationships between the different criteria within the same chemical. The results of these t-tests are shown in Table 12. For each chemical, the difference in mean ratings for each of the three embededdness criteria were calculated to see if they were rated differently from each other within the chemical scenarios. These results were also verified using Analysis of Variance (ANOVA).

Table 11 Correlations between Same Questions, Different Chemicals

Chemical Question Series Compared

		Relevance 1 + 2	Compatibility 1 + 2	Accessibility 1+ 2
ATSDR	Corr coeff.	0.17	0.11	0.29
	significance	x	x	x
Google	Corr coeff	**0.67**	**0.54**	**0.49**
	significance	***	***	***
NLM	Corr coeff.	0.21	0.15	**0.33**
	significance	x	x	*
ICSC	Corr coeff.	**0.58**	**0.56**	**0.70**
	significance	***	***	***
NJ	Corr coeff.	**0.84**	**0.50**	**0.55**
	significance	***	***	***
EWG	Corr coeff.	**0.38**	0.28	0.21
	significance	**	x	x
CHE	Corr coeff.	0.28	0.06	**0.38**
	significance	x	x	**
	Key:			
	Not significant	x	*Significant values are in bold. 10 of 21 are significant	
	Signifcance at 0.10	*		
	Significance at 0.05	**	Chemical 1: ethylene glycol	
	Significance at 0.01	***	Chemical 2: acetonitrile	

Table 12 Comparison of Means Between Same Chemical, Different Questions

	Question 1- Ethylene Glycol						Question 2- Acetonitrile					
	Relevance and Accessiblity	Sig	Relevance and Compatibility	Sig	Compatibility and Accessiblity	Sig	Relevance and Accessiblity	Sig	Relevance and Compatibility	Sig	Compatibility and Accessiblity	Sig
ATSDR	1.52	X	**-2.90**	***	**4.25**	***	**-2.40**	**	**-5.05**	***	**3.05**	***
P value	1.38		**0.01**		**0.00**		**0.02**		**0.00**		**0.00**	
Google	**2.24**	**	**-3.67**	***	**4.55**	***	0.61	X	**-3.17**	***	**2.94**	***
P value	**0.03**		**0.00**		**0.00**		0.55		**0.00**		**0.01**	
NLM	-0.60	X	**-4.65**	***	**4.61**	***	**2.46**	**	**-5.08**	***	**3.12**	***
P value	0.55		**0.00**		**0.00**		**0.02**		**0.00**		**0.00**	
ICSC	-0.37	X	**-4.76**	***	**3.79**	***	-0.47	X	**-3.43**	***	**3.39**	***
P value	0.71		**0.00**		**0.00**		0.64		**0.00**		**0.00**	
NJ	-1.71	X	**-4.13**	***	**4.12**	***	-0.33	X	**-2.44**	**	**2.93**	***
P value	0.09		**0.00**		**0.00**		0.74		**0.02**		**0.01**	
EWG	**-4.41**	***	**-5.82**	***	1.68	*	-1.28	X	**-4.71**	***	**3.90**	***
P value	**0.00**		**0.00**		0.10		0.21		**0.00**		**0.00**	
CHE	**-2.72**	***	**-6.54**	***	**5.07**	***	-0.37	X	**-3.99**	***	**4.23**	***
P value	**0.01**		**0.00**		**0.00**		0.72		**0.00**		**0.00**	

Results of paired t-tests. Consistent with ANOVA showing that the three criteria were different from each other within chemical question.Most were significantly different. Only relevance and accessibility were somewhat similar in some cases.

Key:

Not Significant X

Signifcance at 0.10 *

Significance at 0.05 **

Significance at 0.01 ***

Table 13 shows calculated differences in means for each site and chemical. For example, on average participants ranked the relevance of Google as 2.24, higher than its average rating in terms of accessibility (out of a possible 5). Overall, participants were able to distinguish Relevance from Compatibility and Compatibility from Accessibility for each site. The distinction between Relevance and Accessibility is not as consistently found (in terms of statistical significance) for both chemical scenarios (significant differences are indicated in the columns labeled "Sig" by asterisks). However, sites received significantly different average rankings in terms of relevance and compatibility and compatibility and accountability.

Table 13 Overall Summary Rankings

		Mean	Std. Dev.	Min	Max
ATSDR					
Compatibility		4.21	0.56	3.00	5.00
Accessibility		3.64	0.82	2.17	4.83
Relevance		3.59	0.77	2.00	5.00
Google					
Compatibility		4.24	0.55	3.13	5.00
Relevance		3.80	0.70	2.38	5.00
Accessibility		3.65	0.90	1.17	5.00
NLM					
Compatibility		4.01	0.72	2.50	5.00
Accessibility		3.53	0.82	2.00	5.00
Relevance		3.19	0.85	1.88	5.00
ICSC					
Compatibility		4.17	0.74	2.38	5.00
Accessibility		3.74	1.07	1.00	5.00
Relevance		3.64	0.97	2.00	5.00
NJ					
Compatibility		4.22	0.55	2.63	5.00

Table 13 Overall Summary Rankings

		Mean	Std. Dev.	Min	Max
Accessibility		3.82	0.86	1.67	5.00
Relevance		3.65	1.15	1.00	5.00
EWG					
Compatibility		3.37	0.89	1.00	4.75
Accessibility		2.98	0.82	1.67	4.67
Relevance		2.45	0.96	1.00	4.88
CHE					
Compatibility		3.38	0.80	1.63	4.75
Accessibility		2.72	0.97	1.00	5.00
Relevance		2.40	0.98	1.00	4.75

This means that a given web site was not highly ranked along one dimension just because it was well ranked on another embeddedness dimension.

Given that the participant rankings were consistent across the two chemicals for a given embeddedness criteria, an overall website rating was constructed for each criterion by combining the criterion questions for both chemical scenarios. Summary statistics on combined website ratings for each criterion are shown in Table 13. The table indicates that Google, NJ, ICSC, ATSDR are rated more highly than EWG and CHE in each category. This is more plainly shown in Table 14 where the websites are arranged in ranking order. Google and NJ are the top two in Relevance and Compatibility. NJ is the highest in terms of Accessibility and ICSC is second.

Qualitative website ratings

Data collected during the exercise and in the post exercise interviews regarding the sites provide further insight into the experiences of the participants, consistent with the statistical results in Tables 11 through 15.

Google

Some of the participants found, as a result of this exercise (a result which surprised them) that Google is not the best website to use for the purpose of finding chemical health and safety information. This is consistent with the ERIAL (Ethnographic Research in Illinois Academic Libraries) project which found that the majority of college students studied exhibited significant difficulties that ranged across nearly every aspect of the search process. They tended to overuse Google and misuse scholarly databases. They preferred simple database searches to other methods of discovery, but generally exhibited "a lack of understanding of search logic" that often foiled their attempts to find good sources (44). The search is only as good as the searcher's ability to put in the right key words. One participant noted; "Google can send you on a goose chase if you don't have a specific question" (Participant 4) (45).

Google gives a whole list of resources which many people have written about what to do. (Participant 5) (46). "You could go to Google and get a lot of information but it's general information. Then you can follow the links and you can go everywhere you want, But if you need an answer quick you just need the International Safety Cards" explained one participant (Participant 6) (47).

NJ

This NJ website was reported to be most useful to many of the participants. The participants that preferred the NJ website reported that they would go back to it because it had that one sheet with the important information all in one place. Participants claimed that it had all the chemicals that they were looking for and the information was well-organized and easy to use and helpful. It was easy to find information quickly on the website.

ATSDR

Participants who preferred the ATSDR site found it to be the most helpful because it presents information in a direct, complete, user friendly manner. They reported that it provides all the relevant information such as how someone can be exposed to it and if someone is exposed to it, how they could deal with it. They felt that when they used the search facility they found relevant information about the chemicals. "If you wanted more scientific explanation than you could find on Google, you would probably go for ATSDR because it would take you onto the chemical and you could make decisions" Participant 6 (47).

Table 14 Overall Rankings of Sites Within Categories

		Mean	Std. Dev.	Min	Max	Obs
Relevance						
ATSDR		3.59	0.77	2.00	5.00	33
Google		3.80	0.70	2.38	5.00	32
NLM		3.19	0.85	1.88	5.00	33
ICSC		3.64	0.97	2.00	5.00	30
NJ		3.65	1.15	1.00	5.00	32
EWG		2.45	0.96	1.00	4.88	32
CHE		2.40	0.98	1.00	4.75	31
		Mean	Std.	Min	Max	Obs

			Dev.			
Compatibility						
ATSDR		4.21	0.56	3.00	5.00	32
Google		4.24	0.55	3.13	5.00	33
NLM		4.01	0.72	2.50	5.00	32
ICSC		4.17	0.74	2.38	5.00	30
NJ		4.22	0.55	2.63	5.00	32
EWG		3.37	0.89	1.00	4.75	31
CHE		3.38	0.80	1.63	4.75	31
		Mean	Std. Dev.	Min	Max	Obs
Accessibility						
ATSDR		3.64	0.82	2.17	4.83	32
Google		3.65	0.90	1.17	5.00	33
NLM		3.53	0.82	2.00	5.00	32
ICSC		3.74	1.07	1.00	5.00	31
NJ		3.82	0.86	1.67	5.00	31
EWG		2.98	0.82	1.67	4.67	30
CHE		2.72	0.97	1.00	5.00	32

ICSC

Several participants reported that the ICSC website was the most helpful. The respondents liked the International Safety Cards because they provide all the first aid measures and emergency measures. It was easy to find the information and they liked how it was arranged on the website. Others were impressed with the ICSC because it's brief and very well organized. "ICSC provided the information like symptoms for poisoning and how sick you get. It was very brief bits but it is good information" (Participant 6) (47).

Comparison of website ratings between students and employees

In the next series of analyses, an investigation of whether a participant's status as a student, an employee or a Research Assistant (RA) affected the participant's website ranking was undertaken. In other words, how does employee or student status impact ratings and choices of websites? The embeddedness of a source of information can differ systematically across different groups because of underlying differences in their motivation, culture, and other underlying drivers of the three dimensions discussed above. The intention of this study was to find evidence of these differences for two important subsets of people who work in academic laboratories -- students and employees—in order to understand whether these participant groups have different preferences in terms of sources of information. This has potential implications on the design of relevant web-based information sources for these groups. The data were separated into two main participant groups: students and employees. It was also determined from the questionnaires filled out that a group of the students were also research assistants (RAs) or teaching assistants (TAs).[6]

Employee Rankings

Table 15 shows the site rankings for each criterion for each participant group side by side. The simple comparison of rankings suggests that the students and employees had different rankings of sites along the three dimensions of embeddedness. For example, Google ATSDR and NLM are ranked highest by employees. NJ is the highest ranked site for students in two criteria (relevance and accessibility). Google is highly ranked in two student rankings but only one employee ranking. CHE and EWG are the lowest ranked

---

[6] RAs were a small subset of six students. An analysis was performed to determine whether RA status was different in terms of site ranking than either being a "pure" student or being a "real" employee. T-tests performed found only significant differences between "pure" students and RAs only in three of 27 rankings – Google Compatibility ($t=2.95$, $p=0.025$), ATSDR Relevance ($t=-3.64$, $p=0.0024$) and ATSDR Compatibility ($t=-2.26$, $p=0.04$). Therefore, for all of the analyses involving ranking, students, including RAs, were evaluated as a group.

sites consistently across the criteria for both groups; the highest ranked sites for relevance and compatibility vary between groups.

ANOVA was used to determine whether the student groups' rankings were significantly different from the employees.[7] Table 15 suggests that students and employees did not differ greatly in their rankings except for ratings of ATSDR and CHE. There were few significant differences between students and employees' opinions of the websites and in fact, uniform agreement between ratings for NLM and ICSC.

Behavior – Probabilities of Revisiting Sites

Embeddedness not only concerns whether information is in a form that people can use in making decisions, but also in whether it changes behavior.

Table 15 Ratings Of Websites By Participant Group

		Employee Website Ranking			**Student Website Ranking**		
		Mean	Std. Dev.	Obs	Mean	Std. Dev.	Obs
Relevance							
ATSDR		3.72	0.60	16	3.46	0.90	17
Google		3.72	0.82	16	3.88	0.57	16
NLM		3.45	0.88	16	2.95	0.77	17
ICSC		3.47	0.87	16	3.83	1.07	14
NJ		3.25	1.15	16	4.05	1.04	16
EWG		2.80	1.08	16	2.10	0.68	16
CHE		2.83	1.10	15	1.99	0.66	16
Compatibility		Mean	Std. Dev.	Obs	Mean	Std. Dev.	Obs
ATSDR		4.18	0.51	16	4.24	0.62	16

[7] T-tests of mean differences between students and employees in site ratings result in similar conclusions. Results are available from the author.

Google		4.11	0.49	16	4.36	0.59	17
NLM		4.02	0.70	16	4.01	0.77	16
ICSC		4.12	0.66	16	4.23	0.84	14
NJ		4.11	0.54	16	4.34	0.55	16
EWG		3.60	0.91	16	3.12	0.83	15
CHE		3.59	0.93	16	3.15	0.58	15
		Mean	Std. Dev.	Obs	Mean	Std. Dev.	Obs
Accessibility							
ATSDR		3.77	0.70	16	3.50	0.93	16
Google		3.60	1.03	16	3.69	0.79	17
NLM		3.77	0.76	16	3.29	0.83	16
ICSC		3.74	0.87	16	3.73	1.27	15
NJ		3.65	0.74	16	4.00	0.96	15
EWG		3.21	0.92	16	2.73	0.63	14
CHE		3.10	1.00	17	2.29	0.75	15

In the context of this study we examined whether assessments of the utility of sites predict the likelihood that the sites will be consulted in the future when facing a real decision situation. Whether people would come back to these websites after being exposed to them was assessed using post-test questions that queried whether the participants would continue to use the websites in the future as chemical safety resources. The answers to questions about revisiting sites were used to assess whether the exercise of making people aware of these websites actually could change their behavior. The probabilities of revisiting the websites in the future were assessed.

Overall Likelihood of Revisiting Website

Post-test questions in the survey asked whether participants would revisit any of the websites and, if yes, which ones would they revisit. Due to the limits of this investigation, stated preferences of the participants were considered a proxy for behavior change. Table 9 presents overall the percentages of participants who said they would revisit each site. The top three websites most likely to be revisited were Google, NJ and ICSC. The bottom two websites on the list were EWG and CHE. NLM and ATSDR were in the middle. This order of preference is similar to the ratings order as shown in Table 14 for Relevance. This implies that the higher rated sites in terms of relevance are the most likely to be revisited. This proposition is tested below.

Group Differences

The difference between Students' and Employees' intention to revisit any site as indicated by answers to post-test questions was investigated, since group status might be a significant intervening variable between rating and likelihood of revisit.[8] Table 16 shows the percentages of participants who said they will revisit the websites in the study

Table 16 Ratings Differences Between Students and Employees

	Model		
	F stat*	prob >F*	Signifcance
ATSDR			
Relevance	8.09	0.00	***
Compatibility	2.84	0.07	*
Accessibility	4.01	0.03	**
Google			
Relevance	0.33	0.72	x
Compatibility	4.29	0.02	**
Accessibility	0.73	0.49	x
NLM			
Relevance	2.35	0.11	*
Compatibility	0.02	0.98	x

[8] Two sample t-tests were performed comparing RAs to students and only one significant difference was found in revisit to the ATSDR website. This was because 10 of 16 students did not list ATSDR as a site they would revisit, but some of the RAs did list ATSDR. There were no significant differences between students and RAs in terms of potentially revisiting other website.

Table 16 Ratings Differences Between Students and Employees

	Model		
	F stat*	prob >F*	Signifcance
Accessibility	1.75	0.19	x
ICSC			
Relevance	0.69	0.51	x
Compatibility	0.8	0.46	x
Accessibility	0.18	0.84	x
NJ			
Relevance	3.12	0.06	**
Compatibility	1.25	0.30	x
Accessibility	0.84	0.44	x
EWG			
Relevance	2.31	0.12	*
Compatibility	2.01	0.15	x
Accessibility	1.34	0.28	x
CHE			
Relevance	3.25	0.05	**
Compatibility	2.21	0.13	x
Accessibility	3.27	0.05	**

* Results of Analysis of Variance (ANOVA) of Site Ratings and students and employees.

Key:	
Not significant	x
Significance at 0.10	*
Significance at 0.05	**
Significance at 0.01	***

broken out by student and employee. Google is at the top of both lists and the top four are also the same but the bottom of the order is different.

Table 17 Stated Website Revisitation				
		Overall	Employee	Students
		n=31	n=15	n=16
Website				
ATSDR		39%	47%	31%
Google		84%	87%	81%
NLM		45%	60%	31%
ICSC		68%	73%	63%
NJ		68%	60%	75%
EWG		23%	40%	6%
CHE		19%	33%	6%

Another way to obtain revisit information was to ask the participants to list their site preferences after the exercise. A two sample t-test on the question "Would you use any of the websites in the future?" showed a significant difference between the employee group and the student group. Table 18 illustrates these differences statistically. It shows percentages of participants who said they would revisit each website. The table lists the overall percentages, followed in the next rows by the students and employee percentages. The differences between students and employees were tested by T-Test to see whether any were significant. Significant differences were shown for the CHE and EWG site, and marginally significant for NLM site. The percentage of students who said they would revisit CHE is significantly smaller than those employees who would revisit. By contrast, the percentage of employees who said they would revisit EWG is significantly smaller than the percentage of students who said they would revisit. Because of the significant correlation in several cases, group status was included as a control in analysis of the predictors of return visits in the next section.

Behavior Change

The third area of inquiry in studying the relative embeddedness of chemical websites was whether experience using the site in the experiment would change search behavior of these participants in the future. As stated above, the stated revisit preferences were used as a proxy for behavior change. It was noted previously, that higher rated sites in terms of relevance tended to be those that also had a higher percentage of participants saying they would revisit the site. To investigate whether higher site ratings along the three embeddedness criteria influenced where people said they will go in the future, we estimate the predictors of the likelihood that a participant will revisit a given site using Poisson regression estimators[9] (48).

The Relationship between Ratings and Behavior Change

Table 18 Comparison of Student and Employee Revisit Rates

Subjects	Stat	Google	NJ	ICSC	NLM	ATSDR	CHE	EWG
Combined	Avg.	**0.84**	**0.68**	**0.68**	**0.45**	**0.39**	**0.19**	**0.23**
	SD	0.37	0.48	0.48	0.51	0.49	0.4	0.42
	95% C.I.	(0.70-0.96)	(0.50-0.85)	(0.50-.85)	(0.27-0.64)	(0.20-0.57)	(0.05-0.34)	(0.07-0.38)
Students	Avg	**0.81**	**0.75**	**0.63**	**0.31**	**0.31**	**0.06**	**0.60**
	SD	0.4	0.45	0.5	0.48	0.48	0.25	0.25
	95% C.I.	(0.60-1.03)	(0.51-0.99)	(0.36-0.48)	(0.057-0.57)	(0.057-0.57)	(-0.07-0.195)	(-07-0.196)
Employees	Avg	**0.87**	**0.60**	**0.73**	**0.6**	**0.47**	**0.33**	**0.40**
	SD	0.35	0.51	0.46	0.5	0.52	0.49	0.51
	95% C.I.	(0.67-1.06)	(0.32-0.88)	(0.50-0.85)	(0.32-0.89)	(0.18-0.75)	(0.063-0.6)	(0.12-0.68)
Students - Employees		-0.06	0.15	-0.1	-0.29	-0.16	-0.27	-0.34

---

[9]Logistic and Poisson regression were used to examine whether results were sensitive to choice of model. Results were similar for both high probability outcomes. These results were consistent with logistic regressions which were used since the dependent variable can either take a 0 or 1 value (not return / return).

Table 18 Comparison of Student and Employee Revisit Rates

Subjects	Stat	Google	NJ	ICSC	NLM	ATSDR	CHE	EWG
T-test	t	**-0.3974**	**0.8749**	**-0.6279**	**-1.6239**	**-0.8626**	**-1.9637**	**-2.374**
*T-test conducted to find out whether there were differences between groups.		No sig diff. between groups – both will revisit	No sig diff. between groups – both will revisit	No sig diff. between groups – both will revisit	No sig diff. between groups – both will revisit	No sig diff. between groups – both will revisit	Sig diff btwn groups. Students percentage who will visit is sig. less than employees	Sig diff btwn groups. Employee percentage who will visit is sig. less than students

Statistical methods were used to assess the breakdown by participant group whether the revisit choices correlated with participant's website ratings.

Table 19 Correlations Between Site Ratings and Revisiting by Participant Group

		Employee		Student	
	Embeddedness Category	Correlation Coefficient	Sig	Correlation Coefficient	Sig
ATSDR	Relevance	0.55	**	0.80	***
	Compatibility	0.43	X	0.58	**
	Accessibility	0.63	**	0.75	***
Google	Relevance	0.21	X	0.10	X
	Compatibility	0.49	*	0.08	X
	Accessibility	0.19	*	0.23	X
NLM	Relevance	0.65	***	0.39	X
	Compatibility	0.21	X	0.30	X
	Accessibility	0.35	X	0.67	***
ICSC	Relevance	0.86	***	0.54	**
	Compatibility	0.72	***	0.42	X
	Accessibility	0.90	***	0.54	**
NJ	Relevance	0.49	*	0.69	***
	Compatibility	0.37	X	0.69	***
	Accessibility	0.72	***	0.73	***

Table 19 Correlations Between Site Ratings and Revisiting by Participant Group					
		Employee		**Student**	
	Embeddedness Category	Correlation Coefficient	Sig	Correlation Coefficient	Sig
EWG	Relevance	0.70	***	-0.07	X
	Compatibility	0.41	X	0.21	X
	Accessibility	0.56	X	0.51	*
CHE	Relevance	0.56	***	-0.13	X
	Compatibility	0.69	***	-0.55	***
	Accessibility	0.76	***	-0.35	X
		Key:			
		Not significant	x		
		Signifcance at 0.10	*		
		Significance at 0.05	**		
		Significance at 0.01	***		

Table 19 shows that the employee group ratings for all three criteria for ICSC and CHE are linked to revisiting. Six of seven websites representativeness criterion rating is linked to revisit. ATSDR and EWG ratings for two of the criteria are linked with revisit choices. For Google, NJ and NLM, rating of one criterion is linked to revisit.

In contrast, students' ratings for all three criteria are correlated with revisiting ATSDR and ICSC. Besides those, only the compatibility rating for CHE is linked to revisiting and the accessibility for NLM is linked to revisiting.

In addition to using participant ratings of the three criteria to predict revisiting a given site, the group type (whether the participant was an employee) was also controlled for in the logistic regression. In addition, because of the correlation between the likelihood of returning to a site and group (i.e., employee vs. student), prior experience using the web to find health and safety data ("soughth&sdata") was also included. This is because it is likely that prior experience in using the web for safety and health information is correlated with participant rankings of the sites used in the experiment as well as the likelihood they would return to a given site. Tables 20 to 26 provide the resulting regression estimates. For each website, the table provides the regression results, using relevance, compatibility, and accessibility ratings as the key independent variable. The two other controls were added sequentially.

Table 20 presents these results for the ATSDR site. The columns on the left, grouped under (A) provide logistic estimates for the impact of participant relevance ratings on the likelihood of revisiting. In column (1), just the overall relevance rating of the participant ("atsdrtotalrel") is included. The coefficient (57.7) indicates a very substantial increase in the likelihood of revisiting the site if the participant rated it highly on that dimension. Column (2) adds a control for employee status ("realemploy" =1 if the participant was an employee). The predictive power of relevance rating increases, controlling for that status and remains significant. Finally, controlling for prior use of the internet to find health and safety information does not affect the overall size, sign, or significance of the relevance variable on the likelihood of revisiting.

The middle columns in Table 20 provide a similar set of results, this time using participants' average ratings for compatibility as the key independent variable to predict revisiting the ATSDR site. Once again, high ratings on this criterion are positively and significantly associated with the likelihood of returning. The results are not appreciably changed with the addition of the other two control variables. The columns on the right of the table, grouped under (C) provide the results for ATSDR revisit, this time using participant assessment of accessibility as the key independent variable. Once again, higher ratings of the accessibility of the site associate strongly with the likelihood of return, regardless of introduction of other control variables.

Table 20 ATSDR Revisit Predictions Using Robust Poisson Regression

A

Predicting ATSDR Revisit using ATSDR Total

	Model		
	1	2	3
ATSDR Total Relevance (R.R.)	**4.11**	**5.07**	**4.84**
(95%C.I.)	**2.5-6.75**	**2.79-9.22**	**2.55-9.18**
Constant	0.001	0.000	0.001
(95%C.I.)	0.0002-1.4E 01	2E-05-7.7E-03	3E-5-8E-3
Employee		1.94	1.9
(95%C.I.)		0.95-3.97	0.927-3.79
Previously sought health and safety information on the web			1.11
(95%C.I.)			0.422-2.9
Number of obs	30	30	30
Log pseudolikelihood	-17.93	-17.36	-17.35
Prob > chi2	0.00	0.00	0.00
Pseudo R2	0.22	0.25	0.54
AIC (goodness of fit)	39.86	40.72	42.70

B

Predicting ATSDR Revisit using ATSDR Total

	Model		
	1	2	3
ATSDR Total Compatibility (R.R.)	**3.92**	**4.91**	**4.15**
(95%C.I.)	**0.89-17.36**	**0.85-28.5**	**0.5-4.71**
Constant	0.0010	0.0003	0.0004
(95%C.I.)	9.56e-7-1.04	6.37e-8-1.01	0.61-28.32
Employee		1.97	2.0
(95%C.I.)		0.997-3.9	0.86-3.7
Previously sought health and safety information on the web			1.54
(95%C.I.)			0.5-4.72
Number of obs	29	29	29
Log pseudolikelihood	-20.26	-19.64	-19.44
Prob > chi2	0.07	0.05	0.07
Pseudo R2	0.10	0.13	0.14
AIC (goodness of fit)	44.53	45.27	46.87

C

Predicting ATSDR Revisit using ATSDR Total

	Model		
	1	2	3
ATSDR Total Accessibility (R.R.)	**4.49**	**4.55**	**4.45**
(95%C.I.)	**1.96-10.25**	**1.95-10.6**	**1.85-10.7**
Constant	0.0009	0.0007	0.0007
(95%C.I.)	2e-4-0.4	1e-5-0.035	1e-5-0.4
Employee		1.33	1.3
(95%C.I.)		7.56-2.4	0.76-2.22
Previously sought health and safety information on the web			1.35
(95%C.I.)			0.7-2.64
Number of obs	29	29	29
Log pseudolikelihood	-17.40	-17.27	20.20
Prob > chi2	0.00	0.00	0.00
Pseudo R2	0.23	0.24	0.24
AIC (goodness of fit)	38.79	40.54	42.34

Table 21 Google Revisit Predictions Using Robust Poisson Regression

	A		
Predicting Google Revisit using Google Total Relevance Ratings - Employees			
	Model		
	1	2	3
Google total Relevance (R.R.)	**1.10**	**1.11**	**1.13**
(95% C.I.)	**0.85-1.44**	**0.85-1.44**	**0.87-1.46**
Constant	0.563	0.537	0.53
(95% C.I.)	0.187-1.69	0.18-1.58	0.18-1.55
Employee		1.08	1.1
(95% C.I.)		0.77-1.5	0.81-1.53
Previously sought health and safety information on the web			0.89
(95% C.I.)			0.64-1.22
Number of obs	29	29	29
Log pseudolikelihood	-28.49	-28.47	-28.43
Prob > chi2	0.47	0.65	0.64
Pseudo R2	0.00	0.00	0.00
AIC (goodness of fit)	60.97	51.49	64.86

	B		
Predicting Google Revisit using Google Total Compatibility Ratings -Employees			
	Model		
	1	2	3
Google total Compatibility (R.R.)	**1.20**	**1.23**	**1.24**
(95% C.I.)	**0.82-1.76**	**0.84-1.80**	**0.84-1.84**
Constant	0.38	0.329	0.325
(95% C.I.)	0.07-2.09	0.06-1.85	0.06-1.9
Employee		1.11	1.2
(95% C.I.)		0.82-1.5	0.84-1.61
Previously sought health and safety information on the web			0.90
(95% C.I.)			0.64-1.25
Number of obs	30	30	30
Log pseudolikelihood	-29.43	-29.40	-29.36
Prob > chi2	0.35	0.47	0.63
Pseudo R2	0.00	0.01	0.01
AIC (goodness of fit)	62.86	64.79	66.723

	C		
Predicting Google Revisit using Google Total Accessibility Ratings -Employees			
	Model		
	1	2	3
Google total Accessibility (R.R.)	**1.13**	**1.13**	**1.15**
(95% C.I.)	**0.88-1.45**	**0.88-1.44**	**0.89-1.5**
Constant	0.53	0.518	0.499
(95% C.I.)	0.195-1.42	0.19-1.4	0.18-1.4
Employee		1.05	1.1
(95% C.I.)		0.76-1.44	0.79-1.51
Previously sought health and safety information on the web			0.86
(95% C.I.)			0.63-1.18
Number of obs	30	30	30
Log pseudolikelihood	-29.44	-29.43	-29.38
Prob > chi2	0.33	0.59	0.60
Pseudo R2	0.00	0.00	0.01
AIC (goodness of fit)	62.88	64.86	66.759

Table 22 NLM Revisit Predictions Using Robust Poisson Regression

	A		
Predicting NLM Revisit using NLMTotal Relevance Ratings -Employees			
	Model		
	1	2	3
NLM Total Relevance (R.R.)	**1.98**	**1.94**	**1.78**
(95% C.I.)	**1.46-2.7**	**1.4-2.6**	**1.3-2.5**
Constant	0.040	0.040	0.390
(95% C.I.)	0.01-1.6	0.009-1.73	0.009-0.17
Employee		1.4	1.3
(95% C.I.)		0.65-3.03	0.62-2.8
Previously sought health and safety information on the web			1.63
(95% C.I.)			0.64-4.17
Number of obs	30	30	30
Log pseudolikelihood	-21.47	-21.30	-20.98
Prob > chi2	0.00	0.00	0.00
Pseudo R2	0.10	0.11	0.12
AIC (goodness of fit)	46.95	48.60	49.96

	B		
Predicting NLM Revisit using NLM Total Compatibility Ratings - Employees			
	Model		
	1	2	3
NLM Total Compatibility (R.R.)	**1.39**	**1.47**	**1.32**
(95% C.I.)	**1.4-2.6**	**1.29**	**0.97**
Constant	0.124	0.068	**0.08**
(95% C.I.)	0.65-3.03	-2.02	**-2.08**
Employee		2.02	1.620
(95% C.I.)		1.73	1.07
Previously sought health and safety information on the web			1.8
(95% C.I.)			1.07
Number of obs	30	30	30
Log pseudolikelihood	-23.83	-22.99	-22.59
Prob > chi2	0.25	0.11	0.06
Pseudo R2	0.02	0.04	0.06
AIC (goodness of fit)	51.66	51.99	49.96

	C		
Predicting NLM Revisit using NLM Total Accessibility Ratings - Employees			
	Model		
	1	2	3
NLM Total Accessibility (R.R.)	**2.20**	**2.07**	**2.00**
(95% C.I.)	**3.15**	**2.73**	**2.54**
Constant	0.024	0.250	**0.03**
(95% C.I.)	-3.41	-3.48	**-3.40**
Employee		1.44	1.350
(95% C.I.)		0.94	0.73
Previously sought health and safety information on the web			1.3
(95% C.I.)			..59
Number of obs	30	30	30
Log pseudolikelihood	-21.70	-21.50	-21.40
Prob > chi2	0.00	0.00	0.00
Pseudo R2	0.10	0.11	0.12
AIC (goodness of fit)	47.40	48.99	50.80

Table 23 ICSC Revisit Predictions Using Robust Poisson Regression

A

Predicting ICSC Revisit using ICSC Total Relevance Ratings -Employees

	Model		
	1	2	3
ICSC Total Relevance (R.R.)	**1.66**	**1.70**	**1.71**
(95%C.I.)	**1.24-2.23**	**1.23-2.37**	**1.23-2.36**
Constant	0.099	0.080	0.077
(95%C.I.)	0.27-0.374	0.17-0.4	0.82-1.69
Employee		1.158	1.1
(95%C.I.)		0.77-1.73	0.75-1.65
Previously sought health and safety information on the			1.17
(95%C.I.)			0.82-1.68
Number of obs	27	27	27
Log	-24.17	-24.12	-24.06
Prob > chi2	0.00	0.00	0.01
Pseudo R2	0.07	0.07	0.07
AIC (goodness of fit)	52.34	54.50	56.12

B

Predicting ICSC Revisit using ICSC Total Compatibility Ratings -Employees

	Model		
	1	2	3
ICSC Total Compatibility (R.R.)	**1.73**	**1.77**	**1.77**
(95%C.I.)	**1.12-2.7**	**1.14-2.77**	**1.14-2.8**
Constant	0.070	0.058	0.058
(95%C.I.)	0.00-0.52	0.007-0.48	0.007-0.47
Employee		1.13	1.1
(95%C.I.)		0.79-1.64	0.77-1.66
Previously sought health and safety information on the			1.02
(95%C.I.)			0.69-1.5
Number of obs	27	27	27
Log pseudolikelihood	-25.25	-25.21	-25.21
Prob > chi2	0.01	0.04	0.07
Pseudo R2	0.04	0.04	0.04
AIC (goodness of fit)	54.50	56.42	58.40

C

Predicting ICSC Revisit using ICSC Total Accessibility Ratings Employees

	Model		
	1	2	3
ICSC Total Accessibility (R.R.)	**1.66**	**1.69**	**1.70**
(95%C.I.)	**1.22-2.27**	**1.23-2.34**	**1.24-2.33**
Constant	0.095	0.080	0.079
(95%C.I.)	0.24-0.37	0.18-0.36	0.19-0.33
Employee		1.18	1.2
(95%C.I.)		0.82-1.7	0.80-1.7
Previously sought health and safety information on the web			1.03
(95%C.I.)			0.72-1.5
Number of obs	27	27	27
Log pseudolikelihood	-25.14	-25.07	-25.07
Prob > chi2	0.00	0.01	0.01
Pseudo R2	0.07	0.07	0.07
AIC (goodness of fit)	54.28	56.14	58.13

Table 24 NJ Revisit Predictions Using Robust Poisson Regression

A

Predicting NJ Revisit using NJ Total Relevance Ratings -Employees

	Model		
	1	2	3
NJ Total Relevance (R.R.)	**1.53**	**1.57**	**1.57**
(95%C.I.)	**1.09-2.14**	**1.12-2.19**	**1.123-2.19**
Constant	0.126	0.105	0.111
(95%C.I.)	0.03-0.6	0.02-0.5	0.02-0.55
Employee		1.176	1.1
(95%C.I.)		0.8-1.73	0.823-1.72
Previously sought health and safety information on the web			0.91
(95%C.I.)			0.61-1.35
Number of obs	29	29	29
Log pseudolikelihood	-25.69	-25.63	-25.61
Prob > chi2	0.01	0.02	0.03
Pseudo R2	0.06	0.07	0.07
AIC (goodness of fit)	55.38	57.27	59.22

B

Predicting NJ Revisit using NJ Total Compatibility Ratings -Employees

	Model		
	1	2	3
NJ TotalCompatibility (R.R.)	**2.39**	**2.45**	**2.67**
(95%C.I.)	**1.24-4.62**	**1.23-4.88**	**1.3-5.4**
Constant	0.015	0.013	0.010
(95%C.I.)	0.00-0.33	0.00-0.36	0.00-0.29
Employee		1.068	1.2
(95%C.I.)		0.68-1.68	0.8-1.8
Previously sought health and safety information on the web			0.66
(95%C.I.)			0.44-1.0
Number of obs	29	29	29
Log pseudolikelihood	-26.06	-26.05	-25.67
Prob > chi2	0.01	0.03	0.04
Pseudo R2	0.05	0.05	0.06
AIC (goodness of fit)	56.11	58.09	59.33

C

Predicting NJ Revisit using NJ Total Accessibility Ratings -Employees

	Model		
	1	2	3
NJ Total Accessibility (R.R.)	**2.22**	**2.45**	**2.52**
(95%C.I.)	**1.53-3.22**	**1.53-3.93**	**1.62-3.9**
Constant	0.025	0.014	0.015
(95%C.I.)	0.004-0.144	0.001-0.15	0.002-0.13
Employee		1.3	1.4
(95%C.I.)		0.812-2.12	0.92-2.2
Previously sought health and safety information on the web			0.69
(95%C.I.)			0.48-0.99
Number of obs	28	28	28
Log pseudolikelihood	-23.75	-23.61	-23.28
Prob > chi2	0.00	0.00	0.00
Pseudo R2	0.10	0.10	0.11
AIC (goodness of fit)	51.49	53.21	54.57

Table 25 EWG Revisit Predictions Using Robust Poisson Regression

A

Predicting EWG Revisit using EWG Total Relevance Ratings -Employees

	Model		
	1	2	3
EWG Total Relevance (R.R.)	2.22	1.80	2.28
(95%C.I.)	1.5-3.24	1.27-2.57	2.97
Constant	0.024	0.018	0.015
(95%C.I.)	0.004-0.14	0.002-0.182	1.32-3.9
Employee		3.48	3.5
(95%C.I.)		0.45-27	0.45-27
Previously sought health and safety information on the web			0.38
(95%C.I.)			0.09-1.6
Number of obs	29	29	29
Log pseudolikelihood	-13.90	13.24	-12.77
Prob > chi2	0.00	0.00	0.00
Pseudo R2	0.18	0.22	0.25
AIC (goodness of fit)	31.80	32.47	33.55

B

Predicting EWG Revisit using EWG Total Compatibility Ratings -Employees

	Model		
	1	2	3
EWG Total Compatibility (R.R.)	3.35	2.27	3.40
(95%C.I.)	1.63-6.87	1.12-4.6	1.95
Constant	0.003	0.004	0.002
(95%C.I.)	0.00-0.07	0.4-32	0.99-11.6
Employee		3.61	4.7
(95%C.I.)		0.00-0.07	0.00-0.08
Previously sought health and safety information on the web			0.33
(95%C.I.)			-1.3
Number of obs	28	28	0.06-1.76
Log pseudolikelihood	-14.31	-13.58	-12.92
Prob > chi2	0.00	0.00	0.01
Pseudo R2	0.14	0.19	0.23
AIC (goodness of fit)	32.62	33.16	33.84

C

Predicting EWG Revisit using EWG Total Accessibility Ratings -Employees

	Model		
	1	2	3
EWG Total Accessibility (R.R.)	3.49	2.76	5.38
(95%C.I.)	1.86-6.77	1.19-6.38	1.99-14.5
Constant	0.004	0.004	0.001
(95%C.I.)	0.00-0.06	0.00-0.49	0.00-0.15
Employee		2.7	3.8
(95%C.I.)		0.29-25	0.86-16
Previously sought health and safety information on the web			0.16
(95%C.I.)			0.03-0.9
Number of obs	27	27	27
Log pseudolikelihood	-12.92	-12.50	-11.08
Prob > chi2	0.00	0.00	0.00
Pseudo R2	0.21	0.24	0.33
AIC (goodness of fit)	29.85	31.01	30.16

Table 26 CHE Revisit Predictions Using Robust Poisson Regression

A

Predicting CHE Revisit using Total Relevance Ratings - Employees

	Model		
	1	2	3
CHE Total Relevance (R.R.)	**2.27**	**1.87**	**1.63**
(95% C.I.)	**1.3-3.95**	**1.09-3.22**	**0.87-3.05**
Constant	0.020	0.019	0.015
(95% C.I.)	0.002-0.197	0.00-0.24	0.00-0.145
Employee		2.537	2.5
(95% C.I.)		0.31-20	0.31-19
Previously sought health and safety information on the web			2.37
(95% C.I.)			0.22-25
Number of obs	29	29	29
Log pseudolikelihood	-12.97	-12.68	12.38
Prob > chi2	0.00	0.03	0.01
Pseudo R2	0.16	0.18	0.20
AIC (goodness of fit)	29.94	31.36	32.76

B

Predicting CHE Revisit using CHE Total Compatibility Ratings - Employees

	Model		
	1	2	3
CHE Total Compatibility (R.R.)	**3.74**	**2.94**	**2.15**
(95% C.I.)	**0.45-31**	**0.48-17.7**	**0.43-10.6**
Constant	0.001	0.002	0.000
(95% C.I.)	1.6E-07-9.9	5.91E-07-6.8	5.9E-12-3.35E-07
Employee		2.007	1.1
(95% C.I.)		0.66-6.1	2.77-4.23
Previously sought health and safety information on the web			ERR*
(95% C.I.)			ERR*
Number of obs	28	28	28
Log pseudolikelihood	-11.49	-11.33	-9.63
Prob > chi2	0.22	0.37	0.00
Pseudo R2	0.16	0.17	0.29
AIC (goodness of fit)	26.97	28.66	27.26

* IRR was extremely large and even with repeated iterations did not

C

Predicting CHE Revisit using Total Accessibility Ratings - Employees

	Model		
	1	2	3
CHE Total Accessibility (R.R.)	**2.73**	**2.44**	**2.20**
(95% C.I.)	**1.16-6.43**	**1.18-5.05**	**0.79-6.6**
Constant	0.008	0.008	0.008
(95% C.I.)	0.00-0.28	0.00-0.35	0.00-3.24
Employee		1.69	1.7
(95% C.I.)		0.34-8.4	0.33-8.78
Previously sought health and safety information on the web			1.60
(95% C.I.)			0.08-29.9
Number of obs	29	29	29
Log pseudolikelihood	-12.37	-12.28	-12.20
Prob > chi2	0.02	0.05	0.04
Pseudo R2	0.20	0.21	0.21
AIC (goodness of fit)	28.74	30.55	32.88

Participants' attitudes towards future revisiting were significantly affected by their experience with using the site along the three embeddedness dimensions.[10] (48)

Tables 20 to 26 provide similar analysis for the other six websites evaluated by participants. In each case, the impact of the three embeddedness criteria on revisit likelihood is presented, holding constant the other factors. These results are also presented in Figures 7, 8, and 9. Reviewing these results in a similar manner as the prior discussion leads to the following conclusions:

- The likelihood of revisiting any of the sites was significantly associated with participant ratings of relevance, compatibility, and accessibility, even holding constant employee status and prior experience finding health and safety information.
- The only exceptions to the above conclusion for health and safety websites were for the NLM site with regard to Compatibility ratings; and the CHE site with regard to Compatibility.
- More strikingly, participant ratings of the three embeddedness criteria did not significantly affect the likelihood of revisiting Google for future searches.

This is notable in that participants (students and employees) indicated a high likelihood of revisiting Google for future chemical searches, even though they often ranked the site unfavorably with regard to the embeddedness criteria. This behavior warrants further

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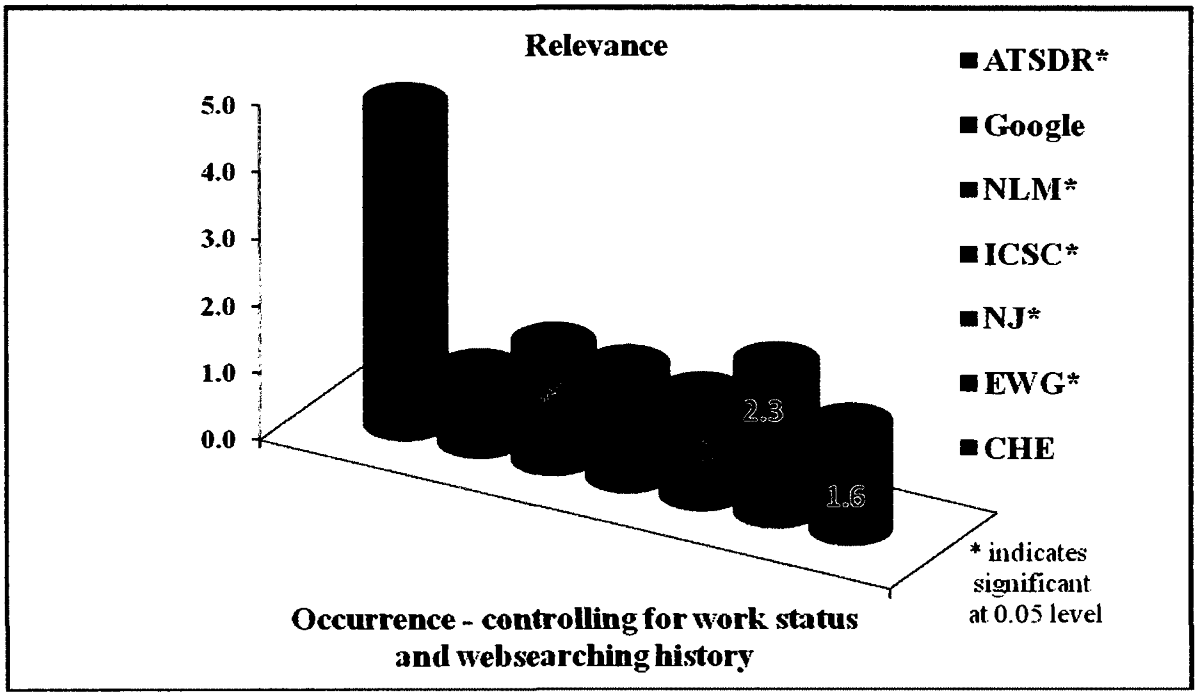
[10] Recall also that participant ratings of the three criteria were not necessarily correlated for a given website. For this reason, I did not construct an overall rating index of embeddedness for each participant since their assessments of a site could differ across the three criteria.

discussion in the next section since it implies that people in academic laboratories might rely on a source of risk information that is actually poorly adapted to that use.

Figure 7 Regression Results: Relation of Relevance Ranking and Revisiting



Google Searches

To prepare for this experiment, Google searches for Ethylene Glycol and Acetonitrile were conducted to mimic the experience of a participant and to find whether any of the study websites appeared in a simple Google search.

Ethylene Glycol and Acetonitrile

Google searches for ethylene glycol and acetonitrile health effects were conducted and found NLM Tox Town as the 4th site listed. ATSDR was the 8th. The NJ website was found as #20 on page 2. Most of the websites in the exercise do not appear in the first

Figure 8 Regression Results: Relation of Compatibility Ranking and Revisiting

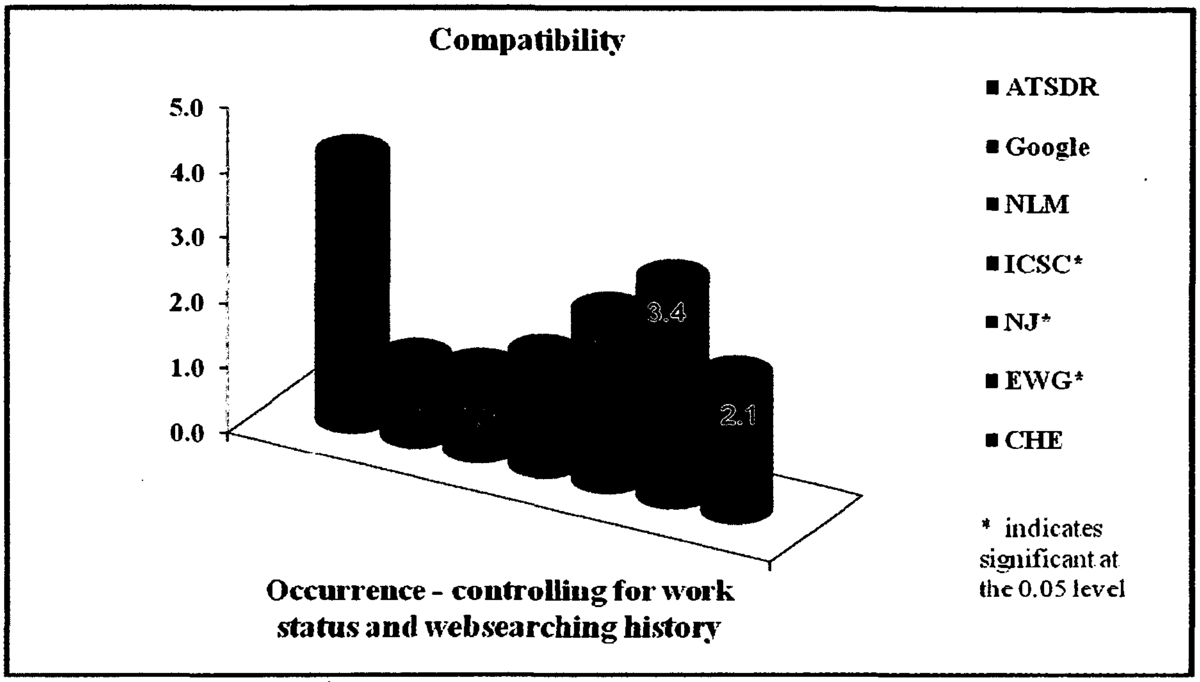
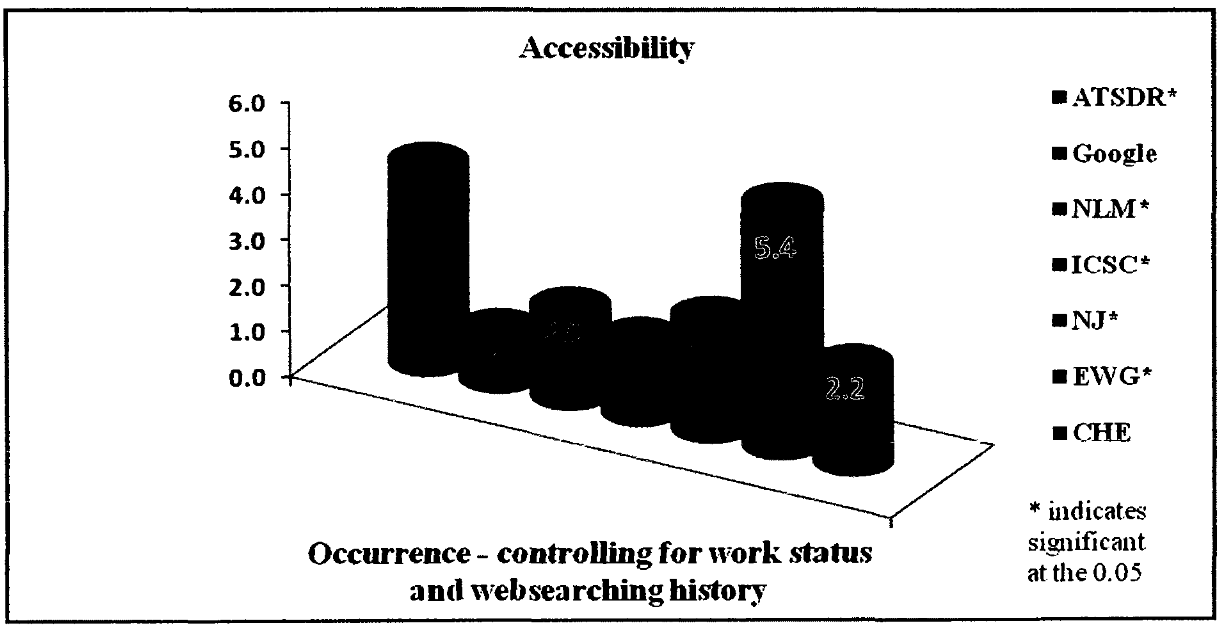


Figure 9 Regression Results: Relation of Accessibility Ranking and Revisiting



page of a Google search. Therefore, if one were not familiar with the web-based resources in this investigation, they would not know to choose them.

The Google search for acetonitrile yielded one Wikipedia entry and three websites about the supply of the chemical. The website entitled "Deadly deceit.com" provides the chemical summary for ACETONITRILE (CAS NO. 75-05-8) that was prepared by the USEPA Office of Pollution Prevention and Toxics in August 1994. There is no information about the organization that sponsored that page. The searches for this chemical and ethylene glycol yielded different types of results than BPA, because these chemicals are not subjects of press scrutiny or popular concern. The search for ethylene glycol yielded more technical results – many of them government documents.

The top five results of each of these searches are presented in Table 27.

Table 27 Top Five Sites Obtained in Google Searches for Ethylene Glycol and Acetonitrile
(Conducted on August 25, 2011)

Ethylene Glycol	**Acetonitrile**
***Ethylene glycol* - Wikipedia, the free encyclopedia** en.wikipedia.org/wiki/ **Ethylene_glycol**	***Acetonitrile* - Wikipedia, the free encyclopedia** en.wikipedia.org/wiki/ **Acetonitrile**
Toxicity, *Ethylene Glycol* emedicine.medscape.com/article/81470 1-overview	**Sigma-Aldrich stocks *acetonitrile* solvent to meet your exact need.** www.sigmaaldrich.com › Chemistry › Solvent Center
***Ethylene glycol* intoxication: MedlinePlus Medical Encyclopedia** www.nlm.nih.gov/medlineplus/ency/art icle/000774.htm	***ACETONITRILE* (METHYL CYANIDE)** chemicalland21.com/industrialchem/organic / **acetonitrile**.htm

Tox Town - *Ethylene Glycol* - Toxic chemicals and environmental ... toxtown.nlm.nih.gov/text version/chemicals.php?id=13	***acetonitrile*** deadlydeceit.com/**acetonitrile**.html
***Ethylene Glycol* | Technology Transfer Network Air Toxics Web site ...** www.epa.gov/ttnatw01/hlthef/ethy-gly.html	**The Great *Acetonitrile* Shortage. In the Pipeline:** pipeline.corante.com/archives/.../the_great_ **acetonitrile**_shortage.ph...

DISCUSSION

Findings

Ratings of Websites

Participants in the study evaluated the seven websites as differing significantly with respect to the relevance, compatibility and accessibility of those sites. Google, NJ, ISCS and ATSDR were consistently rated highly while EWG and CHE were consistently rated the lowest in all three areas. Rankings of sites were basically consistent across the two chemicals that participants were asked to evaluate. However, they often rated a given site quite differently with respect to the three embeddedness criteria. That means that a site might be well received in terms of the relevance of the data it provided, but did less well in terms of how accessible it made that data to the user. Table 28 provides overall ratings for the websites.

Table 28 Overall Website Rankings

Criteria	**Highest**	**Lowest**
Relevance	NJ	CHE
Compatibility	Google	EWG
Accessibility	Google, NJ	CHE

Employees and students working in academic laboratories rated sites somewhat differently from one another in the exercise. For the Employee Group, the ATSDR website was the most helpful and highly rated in all three criteria categories. Possible explanations for this are that the ATSDR website was easy to use and the language was understandable for the non-technical people. In addition, some of the information was translated to Spanish. EWG and CHE are not geared to occupational exposures and were consistently rated low in this exercise. For the Student Group, Google is the most highly rated site in terms of Relevance and Compatibility. The New Jersey RTK website was most highly rated for Accessibility.

Overall, however, it was found that there are not huge differences in the rankings of the websites between employees and students. There was general agreement between the highest ranking sites and the lowest. Employees tended to rate ATSDR and NLM higher than NJ.

Which Sites will the Participants Revisit?

Embeddedness is also closely related to behavior change (26). Results of the study showed that participants varied considerably in their self-assessed likelihood of returning to a site based on their experience in the exercise. The overall likelihood of revisiting is slightly different between students and employees. However, across all groups and sites, Google is consistently rated as the top choice for all subject groups to revisit.

The intention to revisit Google, NJ and ICSC are consistent among the subjects. Only the percentages differ. Students and employees are committed to Google, NJ and ICSC. They universally dislike CHE and EWG.

Statistical analysis found that ratings of sites along the three criteria had a highly significant relationship with the likelihood of returning to them. The major exception to this finding is Google. This was true for both students and employees. Regardless of whether you were an employee or student, or ranked Google high or low, you had an over 80% probability of revisiting Google. Google has become the dominant search engine, the de facto "default" option for most web users. (33) Yet it clearly was viewed as limited in conducting a search for chemical health and safety information. Because of this, an important implication of the study is that designers of web sites for health and safety information must be aware of user search behavior that might lead them to sources of information that are potentially less helpful in providing those exposed to risks the information they need.

Relevance of Cultural Influences and Heuristics on the Internet Search Experience

To understand what makes web-based information useful for the study subjects, the context of the internet searching for chemical health and safety information is important to understand. In the academic environment, this is represented by safety culture of the university and the laboratory. Each person comes to search for information on the internet carrying his own experiences, his own needs, and his own culture with him. This exercise tried to narrow down the problems to be one that could be confronted by people potentially exposed to a chemical in the laboratory. However, Google search culture, lab/safety culture, and personal biases influence the way actual searches are conducted. This was plainly demonstrated by the pre-test questions and the follow-up interviews in the study and will be put in context below.

Google Search Culture

Eleven of 35 subjects reported that they used Google previously to search for chemical information. Seven of those cited use of Google exclusively. This fact is a testament to the predominance of Google as the predominant method of information gathering. According to market research published by comScore in November 2009, Google is the dominant search engine in the United States market, with a market share of 65.6% (49).

Google indexes billions (50) of web pages, so that users can search for the information they desire, through the use of keywords and operators.

General Google Searching

A general search for chemical health and safety information using Google results in many questionably reliable sites and resembles a fishing expedition. This is not likely to be the most effective way to obtain critical safety information in a laboratory situation as shown by the sample of keystroke data. In addition, as described some web-designers design sites to get high ranking on Google, to drive traffic to the website. The ranking of a site in a Google search may not be the most reliable source of information. Thus, the first, most accessible sites that come up are not necessarily the most relevant or the most compatible. Many times the best resources are not found within the first page in a Google search. But many people are used to this Google- type of search and rely, as a short-cut, on the speed of the search. Google is on a quest to provide the fastest results. In fact, Google is introducing a new search feature called Instant Pages, which is intended to give users quicker connections to websites from links on query results (34). Together with optimizing of the websites to get a number one hit makes it difficult to find reliable information. This has implications for making trustworthy web-based chemical health and safety information easily accessible and distinguishable from the noise on the web.

Web Searching and Heuristics

Behavioral researchers have discovered heuristics or mental shortcuts that people use to make decisions. Heuristics are "rules of thumb". They may be educated guesses, intuitive judgments or simply common sense. These ideas originated with Herbert Simon in the 1950s, an economist who wrote about "bounded rationality" (51) and "satisficing". He was responsible for the concept of organizational decision-making as it is known today. Heuristics shape the way people make choices, including how people respond to information about chemical risks. They also explain why Google is the go-to website in situations like those in this study. A particular heuristic may play a role in the default choice of Google. This is the Familiarity Heuristic (52).The familiarity heuristic increases the likelihood that customers will repeatedly buy products of the same brand. This concept is known as brand familiarity in consumer behavior. Due to the familiarity heuristic, customers have the rule of thumb that their past behavior of buying this specific brand's product was most likely correct and should be repeated (53).

This effect can have important implications for search decision making and can influence the decision to do a Google search despite unsatisfactory results. People tend to make health and safety decisions that are based on familiarity and availability as opposed to factual knowledge about diseases (54). They are more likely to take actions and pursue treatment options that have worked in the past, whether they are effective in the current situation or not.

Safety/Lab/Search Culture - University Research Laboratory Culture

The context of this investigation is a university setting, which has many instances of chemical use, from cleaning materials used throughout the university, mercury and asbestos in collections of historical instruments, to silane in nanoscale research labs, to gesso and plaster of paris in art conservation labs. Within this environment, there are opportunities for teaching young scientists and staff people safe and sustainable practices, for changing behaviors using improved information about toxic chemicals, for sharing of surplus materials to reduce waste, and for creating restricted substances lists to reduce toxic use. Susan Silbey, in recent work sponsored by the National Science Foundation, examined the implementation of an environmental management system in biology and chemistry laboratories at a major university. She found that the organization of laboratories, inherent to the study of different sciences influences the culture and adaptation of the management system (55). And from the government's perspective, private educational institutions are notoriously difficult to regulate. Not only do they enjoy a relatively unusual degree of autonomy, but the vast range of activities and dispersed authority create seemingly intransigent obstacles to regulation, especially environmental and workplace safety regulations that were designed primarily for mass production industries (55).

One very important aspect of laboratory culture is power differentials and structured inequality between the Principal Investigators and the graduate students and laboratory staff. When the greater power of management is not taken into account, safety culture advocates fail to recognize the diminished power of those in subordinate positions. Dysfunctional safety consequences are often the result of the hierarchical credibility gap that derives from stratification of personnel. Lower level staff often have to keep track of critical information and are unable to persuade higher-ups in the organization to make changes based on their knowledge (27). This is translated in the laboratory in the lack of time allotted to students to find critical health and safety information for the experiments they are working on.. This phenomenon was reported by many of the students who participated in the exercise. This lack of time influences the search process and emphasizes the need for speed over quality.

The relevance of safety culture

Safety culture is a term often used to describe the way in which safety is managed in the workplace, and often reflects "the attitudes, beliefs, perceptions and values that employees share in relation to safety" (56). There is a trend for safety culture to be expressed in terms of attitudes or behavior. Glendon et al., (57) point out that when defining safety culture the premise of some researchers is to focus on attitudes, where others emphasize safety culture being expressed through their behavior and work activities. In other words, the safety culture of an organization acts as a guide as to how employees will behave in the workplace.

Safety culture refers to a commonly shared, stable set of practices in which members of an organization learn from errors to minimize risk and maximize safety in the performance of organizational tasks and the achievement of production goals. (55) The emphasis on or lack of safety culture pervades university science departments and influences what is acceptable in terms safety practice. Culture determines the commitment to and the style and proficiency of an organization's health and safety programs. If a healthy safety culture is not present even the best safety management systems will not work. An ideal safety culture would propel the organization system toward the goal of maximum safety and health, regardless of the laboratory culture, the leadership's personality or current commercial concerns (55).

Generally, students are not encouraged to spend a lot of time searching for toxicity information on the web (43). But the influence of laboratory culture and safety practices experienced by participant students and workers was found in the post test interviews. The safety tone is set in each lab. The culture of different types of labs was apparent in the participants' post-exercise interviews. Some laboratories were more safety conscious than others. Three students, who participated in the study, came from one chemistry laboratory. They were encouraged to participate in the study by the safety officer in the chemistry department. This is not typical of many chemistry labs though, where little attention is paid to toxicity of materials used (58). However, even some of these students resisted veering from their tried-and-true Google searches or other standard means of finding information. Some were resistant to trying alternative websites, even though they were highly ranked. Another student participant from a biotechnology lab said that because of work with carcinogens and teratogens in the lab, they were more aware of the dangers of potential chemical exposures. (42)

Limitations

Potential weaknesses of the study include small sample size, sources of bias and limits on generalizability.

1. **Small sample size.** The number of subjects (35) was small but spread over two academic institutions. Regardless of size, the results may be generalizable to students and employees at other institutions.
2. **Representative sample.** Although students and employees participated, the employees of Harvard University and University of Massachusetts Lowell were relatively well-educated and probably not representative of employees in many other academic workplaces. A comparison of the years of education of the employee group was more or less similar to the students' academic careers, and in some cases longer.

3. **Lack of custodians in sample.** An attempt was made to enlist the help of the custodian's union but it was not successful. The union representing clerical and technical workers was much more helpful (thank you HUCTW!). This is apparent as many of the employees were members of the union. Results might be different if custodians were the focus of the investigation.

4. **Reproducible results?** If this investigation was expanded to similar populations at other universities, I believe the results would be similar. There may be more or fewer fans of certain websites but those that were favored would stand up to further investigation.

Conclusions

Although websites like NJ and ICSC rated high in the rankings in this study, laboratory personnel, students and employees, like many people, who default to Google searches would not be able to find them if they were not made aware of them. This is a result of several things found in this investigation:

- Lab culture which does not allow time for lengthy searches for information; exhibits a lack of concern for an understanding of chemical toxicity, and has a communication gap between safety professionals and lab personnel.
- Google culture plays a role because we have become accustomed to quick (but not always valuable) results regardless of relevance, and compatibility.
- This tendency to opt for a quick Google search is an example of the familiarity heuristic and is a common occurrence.

In this study it was shown that subjects benefited from exposure to the other websites and that after exposure were more inclined to rank certain ones more highly and favor them for future internet searches. However, if they are not placed higher up in a Google search, or bookmarked, they will be forgotten.

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CHAPTER III

A SHOCK TO THE SYSTEM
HOW ACCIDENTS IMPACT ACADEMIC SAFETY CULTURE

INTRODUCTION

Accidents in academic laboratories can be tragic in terms of loss of life and devastating in terms of damage to university science facilities. Several high profile accidents took place within 2009 and 2010 which have brought increased attention to the issues of laboratory safety. This study investigates three academic laboratory accidents and their impacts on laboratory safety culture at those institutions. The three cases examined involve two fatal accidents and one non-fatal one. Two of these incidents involved employees of the universities and one involved a student. Each of the accidents has had a profound impact on laboratory safety practice at the university where the accident occurred. In two cases, the impacts were felt beyond the confines of the university.

An important concept that is currently prevalent in environmental health and safety circles is "Safety Culture". Facilities with strong safety cultures have strong management commitment to safety and firm dedication to long-term routine practice of safe procedures. Safety culture is thought to be related to the prevention of accidents. The accidents studied here shed light on gaps in the academic safety culture, which Environmental Health and Safety (EHS) and science departments are working to correct. Some common safety issues involved in many academic laboratory situations are availability of reliable chemical information, communication gaps between EHS departments and science departments, heuristics which affect how people respond to information about chemical risks, and insufficient regulatory structures that are supposed to provide oversight to university health and safety programs but often fall short.

This study is a comparative case study of three academic laboratory accidents. The health and safety practices at the institutions that resulted in aftermath of the accidents were evaluated through a safety culture framework. The safety culture framework was derived from an extensive review of safety culture literature.

The goal of this investigation is to examine the extent to which academic laboratory accidents provide motivation for the universities to improve their safety culture and for the academic safety community at large and how this impacts EHS practice and safety culture.

The hypotheses are that:

1. **Universities use accidents as opportunities to innovate and improve safety practices within and outside of the university.**
2. **The root cause (or causes) of an accident are critical for evaluating the responses on the safety practice and culture.**
3. **Two-way communication plays a significant role in laboratory safety culture.**
4. **Existing regulations regarding laboratory chemical management are too weak and ineffective to promote safety culture.**

This paper begins with Section I which is a discussion of the regulatory context of health and safety regulations for private and public academic institutions. Section II then describes the process of choosing the cases and describes in detail, the three major incidents at UCLA, Northwestern University, and Dartmouth College that provide a basis for the evaluation of the impact accidents on the safety culture on these institutions. Section III reviews the literature on safety culture used to develop a model for evaluating the three cases. Section IV evaluates the cases using the safety model in order to explore the hypotheses. Section V describes the data collection and methods used to do the research. Section VI describes the results of the analysis. The paper then concludes in Section VII with a discussion of the implications of the research to the safety culture literature as well as a discussion of policy implications of the research.

SETTING THE STAGE – THE REGULATORY CONTEXT FOR ACADEMIC LABORATORY SAFETY

This investigation of safety culture considers the context of the cases as background. One significant contextual element that must be considered is the regulatory policies relevant to academic laboratories. This introduction describes the regulatory environment which is important to understanding the obligations that academic laboratories as both workplaces and producers of potentially dangerous substances operate. This paper will return to analyze the implications of regulations on safety culture in the discussion section at the end of the paper.

The Role of Regulations in Safety Culture

One set of key external factors that impact the safety environment of academic laboratories is the regulatory environment governing them. The requirements and limitations of statutory coverage of workers and students in academic labs are important to understand as context for prevention of and reactions to accidents.

Safe chemical handling in academic laboratories safety is not adequately regulated by federal laws. In contrast to regulation of biological materials, radioactive materials, and hazardous waste, hazardous chemicals that do not fall under one of these categories are not regulated. Existing regulations, such as they are, provide only loose guidance in terms of chemical handling. A case in point is the United States Occupational Safety and Health Act (OSHA) Hazardous Communication regulations (Haz Com) that require that Material Safety Data Sheets (MSDS) for chemicals in use be present but do not adequately regulate the content of MSDS. Another regulation that plays a role in chemical management in laboratories is the resource conservation and recovery act (RCRA) which prescribes how hazardous wastes are managed. OSHA and RCRA are described here.

OSHA and State OSHA

OSHA regulations are transmitted through the use of the OSHA Laboratory Standard, a policy document meant more as guidelines and supplemented by the National Academy of Sciences' guidance *Prudent Practices in the Laboratory* (1). So compliance with the laboratory standard is voluntary and left to the discretion of the individual facility. Generally, enforcement of OSHA standards is non-existent in academic settings unless there is an accident involving an employee at a private institution.

OSHA has traditionally used "command and control" types of regulation to protect workers. "Command and control" regulations are those which set requirements for job safety (such as requirements for guard rails on stairs) or limits on exposure to a hazardous substance (such as a given number of fibers of asbestos per cubic milliliter of air breathed per hour). They are enforced through citations issued to violators. This requires inspections of facilities by OSHA inspectors. Between December 2006 and December 2011 OSHA inspections were performed 1,149 times on colleges and related institutions (2).

Limits of OSHA Jurisdiction

As shown in Table 29, OSHA does not have jurisdiction over all academic institutions. In general, coverage of the OSH Act extends to all employers and their employees in the 50 states, the District of Columbia, Puerto Rico, and all other territories under federal government jurisdiction. Coverage is provided either directly by the Federal OSHA or through an OSHA-approved state occupational safety and health program, in states that have approved programs. The OSH Act covers all employees except workers who are self-employed and public employees in state and local governments.

Though it is the primary occupational health and safety (OSH) regulation, federal OSHA has no jurisdiction over either employees in public institutions or students at public or private institutions. Federal OSHA covers private employees (professors and staff at private colleges and universities). State OSHA plans in states where they are, may cover public employees in addition to private employees. There is no OSHA jurisdiction over public or private students unless they are employed by the university.

The United States Chemical Safety Board (CSB) pointed out that the OSHA laboratory standard is not enforceable and inadequate for protection against physical hazards(3). As shown in the Table 29, none of the OSH regulations cover students at either private or public institutions. In addition, post-doctoral and graduate students may not even be covered if OSHA has jurisdiction, because they are not defined as "workers".

Table 29 Jurisdiction of Federal and State OSHA for Academic Institutions

Regulation	Private Student	Public Student	Private Employee	Public Employee
Federal OSHA			X	
State OSHA (where available)			X	X

The Hazard Communication Standard

OSHA's Hazard Communication standard (Haz Com), also referred to as the "Right to Know" standard, was issued as 29CFR1910.1200 on November 25, 1983 (48 FR 53280).

It requires developing and communicating information on the hazards of chemical products used in the workplace.

Haz Com was viewed as a new kind of regulation differing from “command and control.” Haz Com gives workers access to information about long-term health risks resulting from workplace exposure to toxic or hazardous substances, and requires manufacturers, importers, and distributors to provide employers with evaluations of all toxic or hazardous materials sold or distributed to those employers. This information is compiled in a form known as a Material Safety Data Sheet or “MSDS”.

Haz Com requires that chemical manufacturers and importers evaluate the chemicals they produce or import and provide hazard information to downstream employers and workers by putting labels on containers and preparing safety data sheets. The MSDS describes the chemical's physical hazards such as ignitability and reactivity, gives associated health hazards, and states the exposure limits established by OSHA. The employer must make these documents available to employees, and requires employers to establish hazard communication education programs. The employer must also label all containers with the identities of hazardous substances and appropriate warnings (4).

Worker “Right-to-Know,” as implemented on the federal level through Haz Com, is designed to give workers access to information so that they can make informed decisions about their exposure to toxic chemicals. In reality, MSDS are inconsistent at best and generally not useful to students and workers who need to find information on toxic chemicals (5).[1]

Global Harmonization System

OSHA is currently working to modify the current Hazard Communication Standard (HCS) to align with the provisions of the Globally Harmonized System of Classification and Labeling of Chemicals (GHS). Under the current HCS all employers must have a hazard communication program for exposed workers, including container labels, safety data sheets, and training (4). This may improve the quality of chemical safety and handling information available to workers and students in academic laboratories.

The primary benefit of the GHS will be to increase the quality and consistency of information provided to workers, employers and chemical users by adopting a standardized approach to hazard classification, labels and safety data. The GHS will provide a single set of harmonized criteria for classifying chemicals according to their health and physical hazards and specifies hazard communication elements for labeling and safety data sheets. Under the GHS, labels would include signal words, pictograms, and hazard and precautionary statements and safety data sheets would have standardized format (4). An example of the pictograms proposed in the GHS revision of MSDS is presented in Figure 10. The bottom of the figure shows the old symbols that the GHS symbols will replace (6).

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[1] Research on the short-comings of existing resources and the potential of valuable alternatives was presented in paper 2 of this dissertation.

The presence of Haz Comm information, awareness of that information, ability to understand it and use it in day-to-day laboratory practice, and the capacity to act on information as a student and / or laboratory worker all have implications on the probability of accidents and health and safety incidents.

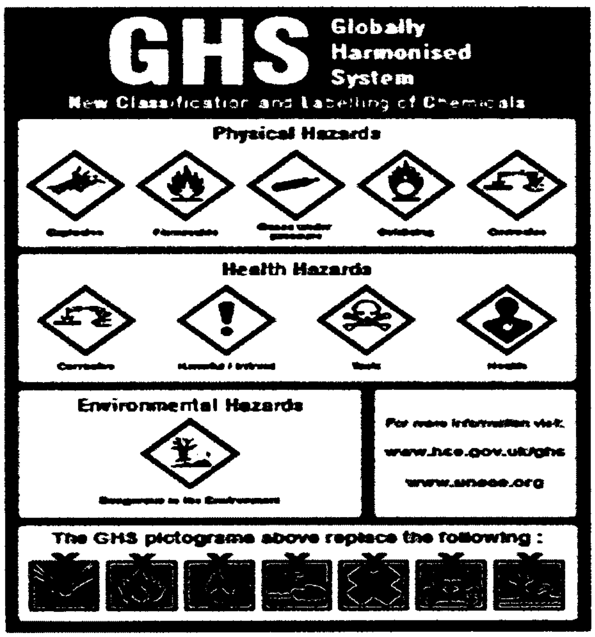
OSHA Laboratory Standard

OSHA's Occupational Exposure to Hazardous Chemicals in Laboratories standard (29 CFR 1910.1450), referred to as the Laboratory Standard, covers laboratories where chemical manipulation generally involves small amounts of a limited variety of chemicals. But this standard applies to all hazardous chemicals meeting the definition of "laboratory use" and having the potential for "worker" exposure. (7) CSB pointed out a major gap in the OSHA laboratory standard is that it does not address physical hazards such as explosions or fires. "The CSB is concerned with laboratory safety because when compared to industry it's an area that is unregulated and lacks good practice guidance," reported CSB Investigator Cheryl MacKenzie (3). In addition, since OSHA does not have jurisdiction over many academic institutions, compliance with the Lab Standard is voluntary.

Hazardous Waste Management

Hazardous waste management is regulated by United States Environmental Protection Agency (EPA) through the Resource Conservation and Recovery Act (RCRA). In 2010 EPA added Subpart K to existing RCRA Regulations. The rule became effective March 7, 2011. The new Subpart is applicable to eligible colleges and universities and teaching hospitals and nonprofit research institutes that are either owned by or formally affiliated with a college or university. The alternative set of regulations allows eligible academic entities the flexibility to make hazardous waste determinations in the laboratory; at an on-site central accumulation area; or at an on-site treatment, storage, or disposal facility (TSDF) (8).

Figure 10 GHS Labeling



This rule also provides incentives for eligible academic entities to clean-out old and expired chemicals that may pose unnecessary risk. The rule also requires eligible academic entities that opt into the rule to develop a Laboratory Management Plan (LMP) which is expected to result in safer laboratory practices and increased awareness of hazardous waste management. However, eligible academic entities may also choose not to opt into the new rule and remain subject to the pre-existing hazardous waste generator requirements (8).

EPA proposed alternative hazardous waste generator requirements applicable to college and university laboratories as defined in this proposed rule. The proposal provides a flexible and protective set of regulations that address the specific nature of hazardous waste generation in college and university laboratories. The flexibility in the proposed rule will allow colleges and universities the discretion to determine the most appropriate and effective method of compliance with today's requirements. Additionally, this proposed rule grants colleges and universities the choice to manage their hazardous wastes in accordance with today's alternative set of regulations or remain subject to the existing generator regulations set forth in 40 CFR 262.11 and 262.34(c) (8). These rules apply to discarded chemicals, and therefore may only have indirect impact on chemical handling in the laboratory.

Summary

This discussion shows the gaps in regulations that impact management of chemicals in academic laboratories. Students are not covered by OSHA or State OSHA regulations, Chemical use in the laboratories are not regulated or restricted until they are discarded as hazardous waste. Chemical information is inadequately regulated by existing HazCom regulations. Information on the impact of regulations and regulatory policy on the safety practices was collected from the cases and used in the analysis. Further discussion of the impacts of these gaps will be discussed throughout the paper and in the discussion section.

CASE SELECTION AND DESCRIPTION

Case Selection

Between 1997 and 2010, there were many major accidents and incidents at academic laboratories. This analysis focuses on three accidents at universities that vary in size, private / public status, and the nature of the incident in order to understand the impact accidents on safety culture and practice. Eligible cases to be included in the investigation were chosen from amongst academic institutions where accidents had occurred in laboratory environments. Unfortunately, there are many examples to choose from. Recent accidents have been reported at Texas Tech(9), UCLA(10), Yale University(11), Boston College(12), and University of Missouri State (3, 13).

The criteria are presented in Table 30. The criteria reflect the fact that information about the accidents had to be accessible through more than one source and primary sources had to be available representing different stakeholders.

Table 30 Criteria for Choosing Cases
Institution had to have had a laboratory accident.
Information about the accident had to be available through literature in addition to first- hand accounts.
Stakeholders at the site had to be willing to talk with the researcher.
The location had to be easily accessible. Several potential sites were identified.

Three schools were chosen as cases for the investigation.

UCLA

Research yielded information about the accident at UCLA which claimed the life of Shari Sangji, a laboratory technician working in the chemistry department. Information about the UCLA accident was readily available through newspaper accounts and through safety practice literature. Dr. James Gibson, the director of EHS at UCLA, was contacted and a meeting was requested. He agreed to meet with the researcher in March, 2011, one week before he was to appear at the American Chemical Society Meeting which took place at Anaheim, California. He also agreed to write a letter to the University of Massachusetts Lowell (UMASS Lowell) Institutional Review Board (IRB), agreeing to participate in the project. Dr. Neal Langerman, a safety consultant living in San Diego, was contacted. He was recommended by Russ Phifer of the American Chemical Society Division of Chemical Health and Safety. Dr. Langerman was interviewed about the UCLA accident and asked for other contacts outside of UCLA EHS who would be knowledgeable about the accident and aftermath. Dr.Langerman enabled contact with several people involved with the health and safety committee of the University Professional & Technical Employees. A meeting was also arranged with Deborah Gold, an inspector from California OSHA who had been involved in the UCLA investigation.

Northwestern University

Information on the laboratory accident that took place at NU in December 2010 was obtained through safety organization literature. The main article on the accident was published in Chemical and Engineering News (C&EN) on January 10, 2011. It was written by the Principal Investigators (PIs) responsible for the Post-Doctoral Student involved in the accident(14). L. Todd Leasia, the Director of the Office of Research

Safety at Northwestern, was also contacted. He agreed to meet with the researcher. He also wrote a letter to the UMASS Lowell IRB, agreeing to participate in the project. He agreed to locate and contact other stakeholders to interview.

Dartmouth College

Information on the laboratory accident that took place in 1997 involving a chemistry professor's exposure to dimethylmercury and her subsequent death from mercury poisoning was obtained through an internet search. Dr. Michael Blayney, the Director of Environmental Health and Safety at Dartmouth, was contacted. He agreed to meet with the researcher. He also agreed to write a letter to the UMASS Lowell IRB, agreeing to participate in the project.

Case Descriptions

The three accidents occurred at University of California at Los Angeles (UCLA) in December 2008, Northwestern University (NU) in November 2010, and Dartmouth College in June 1997. This section describes each case by providing a background on the university in which they occurred, providing background on the university laboratories practices prior to the incident. It then describes the accident itself and the government response to it and the subsequent steps taken by the university. In each description, there is a summary of how the news of the accident was disseminated and some indication of its impact on the academic community is provided.

UCLA

Background

UCLA is a public research institution located in Los Angeles California. It is part of the University of California (UC) system. It offers over 300 undergraduate and graduate degree programs in a wide range of disciplines and enrolls about 26,000 undergraduate and about 11,000 graduate students from the United States and around the world. U.S. News & World Report ranked UCLA, tied with University of Virginia, 2nd among public universities[2]. It was also ranked 25th among national universities (tied with University of Virginia and Wake Forest)(15). *The Washington Monthly* ranks UCLA third nationally with criteria based on research, community service, and social mobility, and first in community service participation(16). The Chemistry Department is ranked 16th in graduate programs in Chemistry in the US News and World Report Ranking(15)[3].

In 1995, of the 36 Ph.D. programs at UCLA examined by the National Research Council, eleven departments were ranked in the top ten(17). Thirty-one of the Ph.D. programs examined were ranked in the top 20, the third highest number of those distinctions in the country. According to *US News and World Report*, many UCLA graduate programs rank

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[2] US News and World Report measures academic quality using criteria in seven areas: peer assessment; retention and graduation of students; faculty resources; student selectivity; financial resources; alumni giving; high school counselor ratings; and (for National Universities and National Liberal Arts Colleges) "graduation rate performance," the difference between the proportion of students expected to graduate and the proportion who do.

[3] U.S. News and World Report uses ratings of academic "experts" to rate graduate programs in science.

in the top 20 nationally, including Chemistry (16), Earth Sciences (17), and Physics (19)(15).

UCLA has approximately 4000 laboratories(18). The incident occurred in the UCLA Chemistry and Biochemistry Department (CBD). CBD employs over 50 professors who pursue research in many areas of chemistry and biochemistry. Their research includes synthesizing complex natural products and nano-materials required to address many health and environmental issues, and investigating the molecular mechanisms that regulate the decoding of genetic information. Research at UCLA cuts across traditional disciplinary boundaries, and the chemistry faculty also play key roles in multiple interdepartmental research units at UCLA, including the California Nanosystems Institute, the Molecular Biology Institute, the Stem Cell Institute, the Institute for Genomics and Proteomics, and the Jonsson Comprehensive Cancer Center(19).

CBD has 1400 undergraduate students majoring in chemistry and biochemistry.
The undergraduate programs are designed to prepare students for graduate studies, for entry into professional schools in the health sciences, and for careers in the chemical and biotechnology industries(19).

Several programs within CBD have approximately 350 Ph.D. students and 130 postdoctoral students engaged in wide-ranging interdisciplinary research under the supervision of the faculty(19).

Existing safety program at the time of the accident

The state of UCLA's safety program at the time of the December 2008 accident highlighted the major deficiencies that caused the accident under study. UCLA received 14 investigations by California Division of Occupational Safety and Health (Cal OSHA) between 2007 and 2010 (2). One particular investigation was conducted just after the December 2008 accident occurred. That inspection found significant deficiencies in several major areas critical to health and safety.

Insufficient internal monitoring of laboratories – Cal OSHA cited UCLA for insufficient internal inspection processes conducted by EHS employees. UCLA EHS staff conducted approximately 1000 inspections (for 4,000 labs) in 2007. That amounts to not even one per year (18). The time frame for correction of deficiencies was 30 days even for serious issues. Even so, follow-up was not done to insure that corrections were made. No one made sure that corrections were made.(20)

Substandard Training – Cal OSHA cited UCLA for insufficient training both in terms of frequency and the specificity of training when undertaken. Specifically, there was no documented training in lab safety in 2007(18).

PPE- Cal OSHA cited UCLA for a deficient Personal Protection Equipment (PPE) training and policy. For example, during the Cal OSHA inspection, the inspectors found someone in a lab wearing a laboratory coat that was too large. The victim of the lab accident was not wearing a lab coat. UCLA was cited for violations of a California Code regarding PPE (20).

Hazard Monitoring - Cal OSHA cited UCLA for insufficient exposure monitoring for hazards in the laboratory (20).

Chemical Storage - Cal OSHA cited UCLA for hazardous chemical storage problems. Water reactive chemicals were stored near showers and acids and bases were stored without secondary containment. Cal OSHA also found problems with construction and locations of chemical storage cabinets (20).

Hazard Communication Issues - Cal OSHA found several hazard communication issues

Improper Labeling -Cal OSHA cited UCLA for improper chemical labeling. They found unlabeled containers of acetone during their inspection(20).

Missing MDSD - MSDS were not available for acetone and isopropyl alcohol in one of the science buildings (20).

Chemical Hygiene Issues - Cal OSHA cited UCLA for an insufficient chemical hygiene plan. The chemical hygiene plan was not updated and was not developed for specific labs. (20). UCLA acknowledged that they did not have a good up-to-date chemical hygiene plan at the time of the accident in 2008. In addition, the chemical hygiene officer did not have the proper training (18).

Injury and Illness Prevention Plan (IIPP) - California requires that every workplace have an IIPP. Cal OSHA cited UCLA for failing to have a functioning IIPP that provides and maintains effective procedures for correcting unsafe and unhealthy conditions (20).

Chemical Handling - Cal OSHA cited UCLA for not having standard operating procedures for handling hazardous chemicals (20).

The Cal OSHA findings indicated significant deficiencies in the state of laboratory safety and EHS at the time of the accident in 2008.

Location of Accident

The Principal Investigator of the Laboratory where the accident occurred was Professor Patrick Harran, who holds the Cram Chair in Chemistry and Biochemistry. He has been at UCLA since 2008. His laboratory is involved in the study of organic chemistry. At the time of the accident, eight graduate students, three post-doctoral students, one research assistant, four undergraduates and one administrative assistant were employed in the lab(21). The Harran Lab website describes its research as follows:

> "*We study architectural aspects of building molecules. This is expressed through exercises in total synthesis, the development of reactions and processes, and in attempts to generally emulate small-molecule biosynthetic schemes. Like others in creative science, we hope to make the gap between 'what is' and 'what might be' smaller.*" (21).

The Harran Lab is located on the 5th floor of the Mol Science Building. Current efforts include second-generation Smac mimetics, targeted inhibitors of the ghrelin acyl transferase and small molecules useful in various aspects of neurobiology research (21). None of the students in the Harran Lab were designated as a safety representative.

After the accident, the Harran laboratory was specifically cited in the Cal OSHA inspection for improper storage of chemicals. In addition, Cal OSHA also cited the improper use of or absence of flame resistant laboratory coats. Lab staff and students had no training in use of fire hoses or showers in the lab(20) prior to the accident.

Event chronology

A search of the OSHA inspection and enforcement records provided the following description of the incident(22).

> *At approximately 3:00 p.m. on December 29, 2008, a research assistant was working in her laboratory and was withdrawing approximately 20 ml. of tertiary butyl lithium in pentane from a sealed container using a plastic syringe. The maximum capacity of the syringe was 60 ml. As she was withdrawing the liquid, the syringe came out of the barrel, causing the mixture to leak out and spill on the research assistant's clothing, torso and hands. Upon contact with air the liquid immediately caught fire. (The compound is pyrophoric and will ignite spontaneously in contact with air.) A coworker smothered the flames with his lab coat. Another coworker threw water from a sink at her. Emergency responders were called and wheeled the research assistant under the laboratory's emergency shower, and then transported her to Ronald Reagan UCLA Medical Center. She was then transferred to Grossman Burn Center located in Sherman Oaks on the same day. The injured worker died on January 16, 2009, while being treated at the Grossman Medical Center.(22)*

Jillian Kemsley, a chemist and the safety reporter for Chemical and Engineering News (C&EN) listed the following things that were problems with how the experiment was being done, besides the fact that the victim was not wearing a lab coat(23).

- She was syringing the *tert*-butyl lithium (tBuLi) rather than cannulating[4].
- She was using a large, plastic syringe that would have been impossible to dry and difficult to handle.
- She was using a too-short needle and likely had to tip up the bottle to get to the liquid, making the syringe even more difficult to handle.
- She had an open flask of hexane in the hood.

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[4] Cannula transfer or cannulation is a technique for transferring solution samples between reaction vessels via cannulae, (stainless steel needles linked by flexible tubing) to avoid atmospheric contamination. It is recommended when working with pyrophoric chemicals. Using a syringe is recommended for less than 50mL. 24. Aldrich. Technical Bulletin AL-134 Handling and Storage of Air-Sensitive Reagents. In: Aldrich S, editor. Milwaukee, WI: Aldrich; 2008.

Strikingly, two years prior to the accident in question, a similar incident occurred in a UCLA BCD lab where a researcher was burned. UCLA safety inspectors found more than a dozen deficiencies in the same lab, according to internal investigative and inspection reports reviewed by The Los Angeles Times. The inspectors found that employees were not wearing requisite protective lab coats and that flammable liquids and volatile chemicals were stored improperly(25). This information is documented in another OSHA incident report filed in 2009 about an accident that occurred in 2007:

> *At approximately 1:30 p.m. on November 17, 2007, Employee #1, a paid graduate student researcher, was working in a university biochemistry laboratory. Employee #1 was performing "flame sterilization" in preparation for plating bacteria. For this procedure, Employee #1 poured ethanol from a glass bottle into a Petri dish and was placing a glass rod in the Petri dish and placing the rod into the flame of a Bunsen burner. Employee #1 accidentally knocked over the bottle of ethanol and the ethanol from the bottle splashed onto his shirt, hands, and onto the floor. There was approximately 50 ml to 100 ml of ethanol in the bottle. The flame from the Bunsen burner ignited the ethanol. Employee #1's hands and shirt were on fire and he patted out the flame with his hands. At the time of the procedure, the screw cap lid was on the glass bottle and Employee #1 is not sure how the contents spilled out. Employee #1 was wearing a polyester shirt over a long sleeve cotton shirt with no additional protection. The polyester shirt melted onto the cotton shirt and the cotton shirt did not burn. Employee #1 walked to the university emergency room with the assistance of a friend. Employee #1 was treated then released with instructions to go to the Burn Center the next morning. Employee #1 went to the Burn Center the next day and was admitted and hospitalized for approximately 7 days with first-degree and second-degree burns on his hands and chest. (26)*

Although this incident occurred in 2007, the OSHA citation was not issued until March 2009, three months after the December 2008 incident occurred. A portion of the citation in the December 2008 incident was therefore cited as a repeat offense(20). It should be noted that both incidents involved paid researchers. Reflective of the previous discussion of the problems in the regulatory framework for academic lab safety, if these victims had been unpaid students, Cal OSHA may not have had jurisdiction to issue a citation.

The UCLA accident came to the attention of the chemical and chemical safety community through reports in Chemical & Engineering News (C&EN) and other technical journals (27, 28). Chemistry Department Chairman Professor Albert J. Courey sent an email to C&EN reporting the incident on Dec. 29, 2008 (29). It became national news as well appearing in the Los Angeles Times, the New York Times and numerous journals (10, 30).

OSHA/Government/Legal Response

As described above, Cal OSHA inspected the CBD and other laboratories at UCLA after the accident and issued extensive citations and fines. In addition, as described above, Cal OSHA cited UCLA in a report released on May 4, 2009 for a long list of deficiencies, and failing to correct unsafe conditions and work practices identified in an Oct. 30, 2008, internal laboratory safety inspection (31). The Cal/OSHA citations carry a total fine of $36,690. It is the largest fine levied by the agency in seven investigations since 2006 that involved academic research labs or the chemical or biotechnology industry. In incidents that involve a fatality, Cal/OSHA routinely forwards its findings to the local district attorney's office to evaluate whether criminal prosecution is warranted(31).

In an unprecedented move, the Los Angeles County District Attorney, on December 28, 2011, brought felony charges against UCLA and Patrick Harran on three counts of violation of the OSH Act. The charges center on a section of the California labor code that makes it a crime for any employer or employee manager to willfully violate any occupational safety or health standard in a way that causes death or prolonged injury to an employee. According to the California penal code, "willfully" means that the employer's actions were not accidental, although it does not imply that the employer intended to break the law or injure an employee. The charges specifically cite regulations involving failure to correct unsafe workplace conditions and procedures in a timely manner, failure to require work-appropriate clothing and personal protective equipment, and failure to provide chemical safety training to employees (32). These are the same sections of the code for which the university was fined in 2009 (29).

Actions taken after the incident

Many deficiencies in UCLA's safety program were identified by Cal OSHA's investigation. In response, UCLA undertook a series of policy and practice steps to address them. A Laboratory Safety Committee was formed shortly after the accident and it reviewed health and safety practice at UCLA prior to the accident and made recommendations for improvements. The safety committee was made up of upper level administration officials, EHS and faculty members. At the insistence of the University Professional and Technical Employees Union (UPTE), a lower level staff person was included on the committee (33). No students took part in this Safety Committee process or currently take part in any decisions about lab safety.

Actions taken to improve health and safety since the accident include the following:

Training - UCLA has started to do specific PI training. "PI training is really helpful in informing faculty about regulatory requirements and their responsibilities," says Hilary Godwin, a professor in the School of Public Health and vice chair of the UC Center for Laboratory Safety's advisory board. "But it's also critical as a way of changing the culture, because if we want the importance of safety to be reinforced throughout the labs, the PIs have to be on board." (34) UCLA went from basically zero documented trainings to 4,000 that in 2007, roughly 6,000 the year after that, to over 11,000 in 2010 (18).

Oversight -The oversight by the EHS department has improved. Penalties for deficiencies have been defined and improvements in follow up have taken place.

Inspections - Inspections are more frequent, more comprehensive. After the accident, structure was added to the inspection plan – including time to make corrections based on the severity of the problem. Labs have 48 hours to correct severe violations, 60 days for less serious ones(18).

Hazard Communication - UCLA has made lectures and safety videos accessible to the public and to other academic institutions. Inside the university many resources have become available to researchers on the EHS website. The information is accessible, reliable and compatible. Some of these include EHS prepared facts sheets and safety videos on subjects such as pipette safety and ergonomics, fire safety, and hazardous waste management. On the UCLA chemistry and biochemistry website there is a safety page where there is an SOP library for common chemicals and chemical groups and how to order a lab coat. Also listed on the chemistry website are PPE policies, a lab safety manual and principal investigator responsibilities (10). These have all been instituted since the accident[5]

Chemical Hygiene Plan - The chemical hygiene plan has been updated(18). The Chemical Hygiene Officer, subject of Cal OSHA criticism, has been replaced in the position by a Chemistry PhD with an expanded job description and an office in the Chemistry Department(35).

Exposure Monitoring - UCLA launched the Laboratory Assessment Tool (LHAT) to inventory laboratory hazards to quantify the risk level of the hazards in the laboratory, and to specify the PPE that's required to be working with those hazards, and verify training and PPE instruction and use. This program is voluntary(18).

These changes have been implemented and are underway at the time of this research. Finally, in March 2010, the University of California, in the wake of the accident, created the University of California Center for Laboratory Safety to support research in laboratory safety and promote best practices in academic laboratories(36). The goal of the new center is to serve as a resource for other institutions to developing programs intended to ensure safety in research labs. The UCLA Chancellor's Office has provided $250,000 in startup funding over three years, while the University of California Office of the President has added an additional $150,000 (36).

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[5] For instance, Policy 907: Safe Handling of Hazardous Substances, dated December 9, 2010 and Policy 905: Research Laboratory Personal Safety and Protective Equipment, dated Feb 1, 2010

Northwestern University

Background

NU is a private research university in Evanston and Chicago, Illinois. Northwestern has 12 undergraduate, graduate, and professional schools offering 124 undergraduate degrees and 145 graduate and professional degrees. It is a large, residential research university. NU enrolled 8,367 full-time undergraduate and 8,108 full-time graduate and professional students in the 2010-11 academic years, along with approximately 1,100 part-time students (37). Northwestern is ranked 12th in the U.S. News and World Report National College Rankings just behind Dartmouth College and ahead of Johns Hopkins University(15)[6]. NU's Chemistry Department is ranked seventh in the U.S. News and World Report Rankings of graduate programs in chemistry(15).

NU has a decentralized approach to safety (38). The NU Office of Research Safety (ORS) handles research safety. Their jurisdiction also includes blood borne pathogens and hazard communication program throughout the university. ORS employs 24 people. There is a second safety department in the Office of Risk Management (ORM). That office handles general occupational safety, fire safety, workers compensation, the insurance function. This office is separate from ORS. Six people in that office have a safety function. A third safety component is facilities management and they handle compliance with respect to environment issues such as underground storage tanks, spill

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[6] See information about US News and World Report College ranking in previous footnotes.

control counter measures, and waste water. Another department handles emergency planning. Institutional emergency preparedness is coordinated by NU Police and the Threat Assessment Group (TAG)(39).

Existing safety program prior to accident

Todd Leasia was the director of NU ORS for 22 years. He retired in October 2011. According to the NU ORS, during his years as director, Leasia advanced the University safety program to a consistent level of regulatory compliance(40). His leadership enabled ORS to receive numerous safety awards, implement ISIS, (the Integrated Safety Information System), triple the size of the department, establish a safety training program for the research community, develop an operations program to oversee waste management, and expand the biosafety, radiation safety, laser safety, and chemical and laboratory safety programs which maintained NU compliance with federal and state safety regulations(40). Todd Leasia stated that he felt that ORS had strong support for its safety efforts from NU Administration.NU was inspected and cited once for a noise violation by OSHA in 2009. That is the only OSHA inspection that occurred at NU between 2007 and 2012(2, 41).

Location of Accident

The accident occurred in a laboratory in the Chemistry Department. The NU Chemistry Department is large and well regarded in the chemistry field(41). It has thirty five research groups and 400 researchers(42).

The Principal Investigator in the lab where the incident occurred is Professor Joseph Hupp, the Morrison Professor of Chemistry. The Hupp laboratory has 12 post doctoral students and visiting scholars, one research associate professor and one program assistant(43). Research in the Hupp Lab is interdisciplinary, with students who are majoring in Physical, Inorganic, Materials and Organic Chemistry working together. Most research projects revolve around a theme of studying materials for alternative energy applications and other environmental issues. Several projects in the Hupp Lab focus on chemical catalysis. Included in these projects is the use of supramolecular porphyrin and salen arrays for the epoxidation of olefins[7]. Due to the interdisciplinary nature of the research, the lab has many joint students with other researchers both at Northwestern and at other institutions. The Hupp Lab is located in Ryan Hall in the Evanston Campus(43). A member of the Hupp Lab also serves as a safety officer.

Event chronology

The accident occurred on Dec. 3, 2010 in the Chemistry Department of NU in Joseph Hupp's laboratory. A Post-Doctoral Student suffered severe but non-life threatening injuries (specifics not available) while performing an experiment with 2-(tert-butylsulfonyl) iodosylbenzene. It was described as a reaction mixture detonation which occurred during an attempt to synthesize 2-(tert-butylsulfonyl)iodosylbenzene, a partially soluble form of iodosylbenzene, that is particularly convenient for use as an oxygen source in studies of catalytic chemical oxidations, such as olefin to epoxide reactions. It was reported that the synthesis had been performed about a dozen times previously at NU and elsewhere without incident. Case Western Reserve had just published an article

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[7] Important because it is the type of work being done when the incident occurred.

documenting this reaction but did not elaborate on variations. The chemical used at NU was peroxide at 35% concentration instead of the 30% described in the article. The following was written in the letter to C&EN "*We do not know with any certainty what caused the explosion. However, the procedure entails combining aqueous H2O2 with acetic anhydride to form peracetic acid. The water component of the aqueous H2O2 solution should serve to remove excess acetic anhydride. We speculate that if some acetic anhydride remained after conversion of the majority to peracetic acid (the desired intermediate compound) or acetic acid (side product), the anhydride could have combined with peracetic acid to form diacetyl peroxide. This organic peroxide is known to be a shock-sensitive explosive.*"(14) Even after making the correction for the concentration, there was an unexpected 20 times increase in the explosive power(44). This was unexpected.

The NU laboratory accident came to the attention of the chemical and chemical safety community through a safety letter written to C&EN by the supervising principal investigators describing the incident and their theories on the cause (14). This article was reproduced on the NU ORS newsletter but no further release of information was made.

OSHA/Government/Legal Response

In Illinois the relevant regulatory body is federal OSHA for private institutions. Illinois operates a public sector only occupational safety and health program under a plan approved by the U.S. Department of Labor. This program provides safety and health protections to state and local government employees within the state. Private sector workers in Illinois are covered by Federal OSHA(45). NU is also regulated by both the state and federal EPA and by Illinois's regulatory board. The regulatory oversight for health and safety at NU is a mix but primarily lab safety is governed by federal OSHA standards. However, even though OSHA had inspected Northwestern in October 2009 and fined the university for a noise complaint earlier, no regulatory agency was involved in the 2010 accident(2, 41). This may be because the victim was a post-doctoral student and not an employee of the university per se.

Actions taken after the incident

Although many good safety practices were in place prior to the accident (as evidenced by the good safety record of ORS)(42), two specific actions were taken at NU to address the issues brought up by the accident. The deficiency that specifically needed correction was the lack of explicit information about the reactions that could be known before undertaking the procedures.

NU hired a safety specialist specifically to work with the NU chemistry department. This hire was in process before the accident but the circumstances surrounding the incident emphasized the need for additional safety resources for the chemistry department (42). According to Todd Leasia, "the new staff person has a chemical engineering background which gives him credibility with the chemistry students and staff. He has worked hard to gain the trust of researchers and PIs and has helped students perform hazard assessments for the projects" (42).

Dr. Hupp related the following story about actions taken following the accident. He noticed that the students in his lab were frightened by the accident because many of them had worked with the post-doctoral student and witnessed the explosion and injury to him. Realizing that their fears had to be allayed so that the research in the lab could continue, he closed the lab for five days. During that time he organized the students into safety assessment teams and had them work on hazard assessments for chemicals and procedures that were occurring in the lab. They adopted a policy of writing up Standard Operating procedures for any new process or reactions thought to pose a greater than normal threat. In addition they identified and posted list of specific chemicals and high-risk procedures that are out-of-bounds for undergrads, first-year grad students, and rookie post doctoral students. This helped to reassure students because group members felt they were gaining some control over the circumstances (44). This process was presented to a meeting of the NU chemistry faculty.

Dartmouth College

Background

Dartmouth College is a private, Ivy League university in Hanover, New Hampshire. The institution is comprised of a liberal arts college, Dartmouth Medical School, Thayer School of Engineering, and the Tuck School of Business, as well as 19 graduate programs in the arts and sciences(46). It was founded in 1769 and is one of the nine Colonial Colleges founded before the American Revolution(47). It has an undergraduate enrollment of 4,196 and a total student enrollment of 5,987. Dartmouth is the smallest school in the Ivy League(46). The Arts and Sciences Department at Dartmouth has 380 tenured and tenure-track faculty members and is among the leaders in percentage of tenured women in the Ivy League. The first Dartmouth Ph.D. was awarded in classics in 1885, and the first modern doctoral programs began in the 1960s. More than 600 students are enrolled in 19 graduate programs in the Arts and Sciences.(47).Dartmouth is ranked 11th in the US News and World Report National University Rankings(15)[8], just behind Duke University and ahead of Northwestern University.

There are approximately 300 laboratories at Dartmouth (48). This includes labs in the Dartmouth Hitchcock Medical Center which is the largest scientific group at Dartmouth. However, the medical school is a separate legal entity but the research space there is included in EHS's responsibility (48).

Dr. Michael Blayney has been the Director of EHS at Dartmouth since 1995. He came to Dartmouth after spending five years as Occupational Safety and Health Specialist and Safety Training Officer at the National Institutes of Health (NIH) in Bethesda, Maryland(49). According to Dr. Blayney, when he arrived at Dartmouth, "there wasn't an effective health and safety program. There were different health and safety elements, but they lacked a common focus and a common leadership approach" (50). "We had a lot of work to do in the beginning, cleaning up the campus, retraining everyone and then this terrible event happened as well"(48). Blayney says, "I've always felt that there has been an institutional commitment to the EHS program. We've developed effective programs that reflect the culture of the institution, the needs of individuals, and the differences among departments."(49) Many improvements have been made to the program before and after the accident. At this time there are nine EHS staff members, plus three Full Time Equivalents (FTs) that deal with laboratory-related safety(50).

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[8] Please refer to previous description of US News and World Report college ranking criteria.

The accident occurred in a chemistry research laboratory. The chemistry department is small, with a student: faculty ratio of about 2:1. Dartmouth chemistry graduate students come from around the US and the world (currently 13 states and 5 countries) (46). There are 15 faculty members, four emeritus faculty members, two senior lecturers, six adjunct faculty members, and two research faculty members(51). Only a small fraction of these instructors were at Dartmouth in 1996, when the accident occurred.

Location of the Accident

The accident occurred in Dr. Karen Wetterhahn's chemistry laboratory. She was the Albert Bradley Third Century Professor in the Sciences. Her research focused on toxic metal exposures. Dr. Wetterhahn was the first tenured female professor in the sciences at Dartmouth. She also helped found the college's Women in Science Project to encourage more young women to follow her path. And she brought in the single largest grant anyone at the college had ever received: $7 million to work on toxic heavy metals in the Northeast. At the time of her accident, she was studying where the heavy metals were, how they affected people and what could be done about them. Her work was aimed largely at understanding how mercury and other metals can induce cancer and other illnesses by disrupting a particular protein in its usual function of repairing damaged DNA(52).

Event chronology

The accident occurred when Dr. Wetterhahn, working alone in her laboratory on August 14, 1996, was using dimethylmercury as a standard for her mercury measurements investigations using nuclear magnetic resonance (NMR) spectroscopy to investigate the binding of mercury ions to a protein involved in DNA repair. Dr. Wetterhahn wore proper, recommended Personal Protection Equipment (PPE), including a laboratory coat, goggles and latex gloves and she was working in a fume hood.

Starting in January 1997, Dr. Wetterhahn began to experience tingly fingers and toes, slurred speech, and balance problems, and then constricted vision and hearing loss. She was diagnosed on January 28, 1997 with mercury poisoning. At that time her blood mercury exceeded the toxic level 80-fold. Three weeks later, she lapsed into a coma, in which she remained until she died in June 1997 (53).

At the time of Dr. Wetterhahn's admission to the hospital, she reported two separate occasions when she spilled a tiny amount of the chemical on the dorsum of her left hand near the junction of her forefinger and thumb. She also reported cleaning the spilled material up-which, presumably, included removing her gloves and washing her hands.

The MSDS on the dimethyl mercury, issued by the company that supplied it, Alfa Aesar of Ward Hill, Mass., warned that the chemical was potentially lethal and that even a short exposure was dangerous. It described several strict precautions that should be taken in working with it, but in the listing on what kind of protective gloves should be worn; only "rubber" appeared(52).

A great deal was known about the toxicity of organic mercury at the time of the accident. Ingestion of fish or grain contaminated with methylmercury resulted in epidemics of severe neurotoxicity and death in Japan in the 1950s and in Iraq in 1972(54). The World Health Organization and other organizations warned of the dangers of methylmercury compounds to the environment and to scientific researchers . However, there was insufficient information at the time about specifically how toxic dimethylmercury was and how easily it would go through rubber gloves. Subsequent research found that only one type of glove could prevent dermal contact from dimethylmercury (55). According to the OSHA Safety Hazard Bulletin on dimethylmercury, highly resistant plastic-laminate gloves such as Silver Shield, are required.(56)

The accident involving Professor Karen Wetterhahn from exposure to and acute toxicity of dimethylmercury at Dartmouth was subject of national news (52, 57). Doctor Wetterhahn's death touched an unusually large number of people judging from the breadth with which it was reported in the scientific and lay communities. (58)

OSHA/Government/Legal Response

Dr. Blayney called OSHA to the Dartmouth campus after Dr. Wetterhahn's death. OSHA cited Dartmouth for not providing training on the limitations of protective gloves in the laboratory and the College's chemical hygiene plan for not being explicit about the uses of the gloves. Given the state of knowledge at the time of the accident, not even those preventive measures would have saved Dr. Wetterhahn. No one, including OSHA, was aware of dimethylmercury's ability to instantly penetrate latex gloves until Dartmouth had the testing done. Nevertheless, OSHA fined the College $13,500 and required

Dartmouth to hire a chemical hygiene officer and increase its safety instructions, especially on gloves (59).

OSHA later reduced both the number of violations it had initially determined that Dartmouth had committed and the associated penalties because the college had taken such swift action to improve conditions as well as alert the scientific community to the danger of mercury compounds (53).

OSHA revised its original letter of citation by reducing the number of specific cited violations and by reducing the penalty from the previously proposed $13,500 to $9,000. In turn, Dartmouth restated its plans to continue additional training on choosing and using chemically resistant gloves, hire a campus-wide chemical hygiene officer and to form a committee to address chemical safety across the campus (60).In addition As a result of the accident, OSHA revised the Safety Hazard Information Bulletin on Dimethylmercury (56).

Actions taken after the incident

After her death, colleagues of Dr. Wetterhahn, including Michael Blayney contacted the ACS, which published a warning about the dangers of dimethylmercury as soon as possible. The article recommended that highly resistant laminate gloves (SilverShield or 4H) should be worn under a pair of long-cuffed, unsupported neoprene, nitrile, or similar heavy-duty glove. (55)

An independent laboratory tested all the gloves in Wetterhahn's lab, finding that dimethylmercury penetrates latex and polyvinylchloride (PVC) almost too fast to be measured. A drop could transfer from glove to, and through, skin in 15 seconds. And although symptoms don't appear for months, the compound rapidly crosses the blood-brain barrier and begins its destruction, so that chelation therapy to trap and remove mercury does not work (53).

At Dartmouth after Dr. Wetterhahn's death, many safety improvements were made in Wetterhahn's memory. Workshops instructed scientists in selecting appropriate gloves. The latex gloves that are fine for most biomedical research are not sufficient for extremely toxic chemicals; use of such substances requires laminate gloves worn under long-cuffed neoprene gloves. Gloves are now color-coded to posters that match glove type to task. And in many research laboratories at Dartmouth and elsewhere, less-toxic mercury salts replaced dimethylmercury as an NMR standard(53).

At Dartmouth, a chemical safety committee was formed and a chemical hygiene officer hired. According to Michael Blayney, the health and safety program was revamped after this event and over time has become the functioning system that it is today(48).

LITERATURE REVIEW - SAFETY CULTURE AND SAFETY CLIMATE

This section reviews the literature in the areas of Safety Culture and Safety Climate including information where and how they have been used, and on research methods for both concepts. Safety Climate literature will be reviewed first, followed by Safety Culture, then there will be a discussion of the differences and similarities and the role each plays in an academic safety culture research. The concepts of safety culture and safety climate arose together and then diverged. Drawing on this review, a safety culture model involving both safety climate and safety culture elements applicable to colleges and universities is proposed at the end of this section.

Safety Climate

Definition of Safety Climate

The concept of work climate in the literature predates culture by about 40 years. The term "Safety Climate" was originated by Dov Zohar in an empirical investigation of safety attitudes in Israeli manufacturing. He defined it as "...a summary of molar perceptions that employees share about their work environments" (p. 96) (61). This more recent definition was provided by Cooper and Phillips:

Safety climate refers to the degree to which employees believe true priority is given to organizational safety performance, and its measurement is thought to provide an early warning of potential safety system failure(s)(62). Even more recently, Fugas presented this statement about safety climate: *"Safety climate reflects a psychological environment that provides a motivational antecedent to safety behaviors"* (63).

Safety Climate Investigations

Researchers have struggled over the last 25 years to find empirical evidence to demonstrate actual links between safety climate and safety performance(62). Safety climate inquiries were conducted in several industries such as Australian mining and manufacturing(64), health care (65), steel industry(66), and the United Kingdom Offshore oil and gas industry(67). In most safety climate inquiries, the purpose of measuring safety climate was to provide opportunities for inquiry or to make changes in safety practice to improve safety performance in that organization (62).

Griffin and Neal proposed that safety climate should be classified as an antecedent of safety performance(64). They qualified this finding by the statement that the relationship between safety climate and safety performance may be mediated by determinants of safety performance, such as safety motivation and safety knowledge. This statement acknowledged that values and the mission of the organization are critical factors in safety practice. Yule found after reviewing the safety climate literature, that the overwhelming impression it left was that safety climate research has been conducted for 20 years with no great consensus regarding the important factors or questions to ask, save that they should be measured by means of a workforce questionnaire.(68)

Benefits of Safety Climate Research

Regardless of Yule's conclusion, safety climate was found not only to have a strong association with safety behavior, but also with psychological well-being(69). Much of the safety climate research has been done by European psychologists.

A study by Clarke and Ward (70) linked organizational safety climate to employee safety performance. However, they found that the relationship between safety climate and accident involvement was found to be moderated by research design. Their conclusions could only be validated when accident occurred following the safety climate investigation. Their study provided some evidence for the contention that improving safety climate significantly affects the enhancement of employee safety performance and accident prevention(70).

Safety Climate and Safety Practice

Dov Zohar, the father of safety climate, presented the results of a meta analysis of safety climate studies in 2007 and argued that his findings showed that Safety Climate mediates organizational culture and employees' behavior – and explains 22% of injuries (71). Keren et al. demonstrated that level of safety climate is likely associated with the selection of safer choices(72). Seo (73) demonstrated that safety climate had a significant indirect effect on unsafe behavior through the removal of perceived barriers to safety (i.e., reducing attitudes of skepticism regarding the importance and efficacy of safety measures and procedures); Griffin and Neal found that safety knowledge and, to a lesser extent, compliance motivation were significantly predictive of safety compliance(64).

Limitations of Safety Climate Research

Several limitations to safety climate research were identified in the literature. Two prominent ones are as follows –

a. The lack of empirical evidence to demonstrate actual links between safety climate and safety performance (62).

b. A factor in safety climate should only be viewed as key if it predicts actual, or ongoing, safety performance in organizations (74).

The reported relationships between safety climate and safety behavior have largely been inferred from models based on self-reporting instruments. The notable exception to this trend is Glendon and Litherland's attempt to measure both safety climate perceptions and actual safety behaviors in road construction (62).

Safety Culture

It is important to this investigation to understand both safety culture and safety climate. The interest in safety culture has blossomed in the safety world over the last twenty years, especially in Europe. The hypothesis in safety culture research is that there is a connection between an organization's cultural traits and the level of safety in the organization(75) and that a healthy safety culture can prevent accidents. An organization's safety culture provides grounds for proactive safety management, and provides predictive measures which may reduce the need to wait for the system to fail in order to identify weaknesses and to take remedial actions(74) (p. 178). The hope is that such ‘predictive measures’ will be precautionary rather than reactionary indicators for the management of safety.

The term safety culture was first officially used in an initial report about the Chernobyl accident (International Atomic Energy Agency (76). This report introduced the concept to explain the organizational errors and operator violations that created the conditions for the disaster. Other efforts have since sought to test the precautionary hypothesis and found poor safety culture within facilities as a determinant of several high-profile accidents since, such as the explosion on the Piper-Alpha oil platform in the North Sea (77); the fire at King’s Cross underground subway station(78); the sinking of the Herald of Free Enterprise passenger ferry(79); and the passenger train crash at Clapham Junction (80). All four of these accidents occurred in Europe and set the stage for safety culture surveys that were conducted in many European industries. Safety culture became a framework through which safety practice at these facilities could be assessed and “a culture cure” diagnosed to avoid accidents.

Antonsen (2009) argued that culture influences safety in two ways. First, it provides the frames of reference through which risk information is interpreted and possibly describes a field of vision, where some risks are visible, but where there may be blind spots regarding others. Second, culture also influences safety by creating conventions for behavior, interaction and communication, both formal and informal.(81)

Safety Culture Definition

In contrast to safety climate, an organization's safety culture is ultimately reflected in the way in which safety is managed in the workplace. The term 'safety culture' was introduced in 1986 by the International Atomic Energy Agency (IAEA) in a report on the Chernobyl nuclear power plant disaster (76). A great deal of research has taken place on Safety Culture since the Chernobyl accident. Many definitions of safety culture can be found in the literature. A working definition of Safety Culture is found in the quote below from the British Health and Safety Commission (HSC):(82)

> *Safety culture consists of values, attitudes, perceptions, competencies and behavior of the people regarding safety that make up the organization. In an organization with a positive safety culture there are high levels of trust; people agree that safety is important and that safety management systems are effective. This definition implies that a poor safety culture would be one where people do not trust each other, and do not share the perception that safety is important and that preventative measures are effective*.(83, 84)

Other definitions of safety culture include social norms and unspoken rules of behavior that, if not followed, result in sanctions (85). Understanding the safety culture of an organization, work site or work-group as a whole may be difficult but identifying and understanding the dominant safety norms may be more manageable (68). This "atmosphere" is important for understanding the factors that may influence safe practices.

Yule conducted an extensive literature review of two concepts: safety culture and safety climate (68). He traced the history of both concepts and tried to distinguish them from each other. His summary is extensive and includes literature up until approximately 2002.

He and his colleagues at the University of Aberdeen have conducted much of the foundational research on safety culture. The following includes a synopsis of Yule's and others' findings on safety culture research supplemented with more recent literature where available.

Safety Culture Research Methods

Qualitative methods are generally used to research safety culture research in an organization. Because Safety Culture components are beliefs and values, qualitative methods have been determined to be the most effective means to analyze safety culture. Methods that have generally been used to measure safety culture include interviews, questionnaires, focus groups, audits, and expert ratings. Questionnaires have predominated as the main safety culture research method. All but one of the seven empirical articles in Journal of Safety Science's special issue on safety culture (86) used survey tools. Following this lead, the American Chemical Society Division of Chemical Health and Safety (DCHAS) recently conducted two safety culture surveys of the general membership and of academic safety officers in particular(87, 88) .

Some researchers have developed survey tools and toolkits to evaluate safety culture. Examples of safety culture survey tools include the 'Health and Safety Survey Climate Toolkit' (89), and the 'Safety Culture Assessment Toolkit' developed by the British Health and Safety Executive (HSE).(86). These tools have become more and more elaborate in recent years.

Understanding individuals' attitudes and behaviors at work has been recognized as important since Hawthorne's classical studies in the 1930s (63)[9]. Some studies have measured safety culture using a case study format to report findings. There are case studies of several types of organizations, including high reliability organizations, comparisons of high and low accident plants, and narratives of organizational crises. Studies that have measured safety culture have used qualitative methods to investigate safety culture. Some also developed quantitative analyses on the basis of those results (e.g., Lee (90) see section 2.2.4.2).

Safety Culture and Accidents

Investigations of safety culture and major accidents that identify the impact of organizational culture may provide insights into the source of the accident and several inadequacies of that culture and ways in which it might be improved (91). These were reviewed to investigate how the study of safety culture of organizations in crises helped identify root causes and culture issues within companies. There is a great deal of precedence for studying safety culture in the aftermath of accidents which makes it appropriate for the study of academic accidents that are the subject of this investigation.

A study by Turner and Pidgeon of several man-made disasters identified a number of practices which amount to a culture of risk denial(92).Their study was based on official reports alone and not on direct inquiries or interviews. A second accident study was

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[9] The Hawthorne Studies, which were conducted in the 1920s and 1930s at Western Electric, sparked an increased emphasis on the social and informal aspects of the workplace. Interpretations of the studies emphasized "human relations" and the link between worker satisfaction and productivity.

conducted by Vaughan on the Challenger space shuttle disaster in 1986. This was a study of organizational culture and how it contributed to disaster. Vaughn identified cultural elements including: the normalization of deviance and the culture of production and structural secrecy, and showed how they contributed to the disastrous outcome(93).

Three retrospective analyses of major disasters are: a public inquiry into the King's Cross fire (78); a Presidential commission inquiry into the Challenger (93); and an OSHA inquiry into the nuclear accident at Three Mile Island (94). All three of these reports identified poor safety culture as a contributing factor to the accident. Characteristics of poor safety cultures frequently include an absence of management commitment, poor housekeeping, lack of organizational learning, and productivity or meeting schedules being more important than personnel concerns about safety (91). These poor safety culture components contrast with the positive versions of the same components that characterize low accident plants found by Lee (90).

A logical conclusion from these findings is that poor safety culture may be related to higher probabilities of both individual accidents and organizational-level accidents (i.e., major disasters). However appealing this idea is, all these evaluations were performed retrospectively and may have no predictive power in determining whether or where the next accident might occur (68). Nevertheless, characterizing the safety culture of organizations in crisis could provide important data points to consider when attempting to avoid future incidents (e.g., (68, 74).

According to Weigmann et al. (95) a major turning point for "safety culture" in the United States came with an aviation accident—the in-flight breakup and crash of Continental Express Flight 2574 near Eagle Lakes, Texas, on September 11,1991 that killed 14 people. A member of the National Transportation Safety Board (NTSB) at that time suggested that the probable cause of this accident included the failure of the airline management to establish a safety culture that encouraged and enforced adherence to approved maintenance and quality assurance procedures. (NTSB/AAR-92/04, 1992, pg. 54, as cited in (95). As a result of this and other similar aviation accidents, safety culture came to the forefront as the exclusive topic at the U.S. National Summit on Transportation Safety, hosted by the NTSB in 1997.

Safety culture is often identified by disaster inquiries as being fundamental to an organizations ability to manage safety related aspects of their operations, successfully or otherwise(96). Although, knowledge of the relationship between culture surveys and safety is limited (75), understanding safety culture is key in developing different insights on where and how to improve safety management processes (97).

Comparative Case Studies using a Safety Culture Framework

Comparative studies of safety culture have focused on the characteristics of 'safe' (i.e., low accident) versus 'unsafe' (i.e., high accident) worksites and departments. This was amplified by one study that (86, 98) examined 13 European manufacturing plants in the same company. They concluded that plants with low accident frequencies had employees with more positive attitudes to safety, greater evidence of management commitment to safety, higher levels of compliance, and better-managed hazards (90). The main characteristics of low accident plants are: high frequencies of informal safety communication; evidence of good organizational learning; strong commitment to safety by senior management; democratic and participative leadership style; safety procedures and values emphasized in skills training; good housekeeping; high levels of job satisfaction, and safe work. In this type of plant, these components function as criteria for recruitment and retention distinct from productivity.

Safety Culture Evaluation Example

A recent safety culture evaluation after an accident demonstrated provides an example of a post-accident safety culture analysis and how it can be used to promote safety practice. In 2008 a spill of plutonium occurred at the National Institute of Standards and Technology (NIST) in Boulder, Colorado. A group of independent experts, including Richard Toohey[10] (99), was asked to conduct an investigation to identify the cause(s) of the incident and any contributing factors, evaluate the response to the incident, review the report, and make recommendations to avoid further incidents.

As part of the investigation, Toohey evaluated the safety culture at NIST using a DuPont Safety culture model(99). There are five stages in the DuPont Safety Model in order increasing levels of safety or decreasing risk:

1. Safety is an externally-imposed requirement by the Nuclear Regulatory Commission (NRC), OSHA, EPA, etc.
2. Safety is the responsibility of the internal safety and health staff.
3. Safety is a line management responsibility.

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[10] Richard Toohey is the Director of Dose Reconstruction Programs Oak Ridge Associated Universities.

4. Safety is the responsibility of each individual.
5. Everyone is responsible not only for their own, but also for everyone else's safety.

Toohey reported that the safety culture at the facility appeared to be at Stage 2, which is a high-risk condition. Stage 2 means that safety is the responsibility of the internal safety and health staff and not the responsibility of anyone else in the facility.

He also identified specific examples of how the poor safety culture was demonstrated in the NIST workplace:

- Managers expect safety staff to fix problems, rather than to advise them how they should fix the problems.
- Safety personnel have been told that safety must not interfere with creativity.
- Safety personnel have stop-work authority, but are reluctant to use it. Most believe they would receive management support, but would also receive significant "push-back" from the research staff and damage their working relationships.
- Safety personnel prefer an "informal" approach by personally working with researchers to facilitate their work from a safety standpoint, rather than a formal program of review and oversight. Consequently, no line manager is required to make a decision on risk acceptance (99).

This NIST example illustrates how safety culture analysis might be used to assess the safety state of an academic facility. Toohey investigated the cause of the accident and measured the safety practices at the NIST facility against the DuPont safety culture framework and then pointed out deficiencies that could be corrected to improve safety culture at the facility and prevent future accidents.

Safety Climate and Safety Culture

A review of the Safety Culture literature resulted in reviewing a large amount of research on both Safety Climate and Safety Culture. Safety Climate and safety culture are related and are often confused. Generally, the safety climate is a macro scale phenomenon in an organization. Safety culture is more small scale and is relevant within a department or a group. The definitions of safety climate are closely related to those of safety culture, and both are included here because of their interrelationship and importance in Academic Laboratory Safety.

Procedures versus Values

Guldenmund (100) provided an extensive analysis of safety climate and safety culture investigations conducted up until 2000. He pointed out that shared aspects are stressed in both sets of definitions and that the main differences are that safety culture is characterized by shared underlying beliefs, values, and attitudes towards work and the organization in general. In contrast, safety climate appears to be closer to operations, and is characterized by day-to-day perceptions towards the working environment, working practices, organizational policies, and management(68).These are very close definitions and not unrelated. In fact, Antonsen recently argued that there are no clear conceptual differences or other distinctions between studies of safety climate and studies of safety culture and that the main difference is in research methodology(81). Table 31 summarizes an understanding of the characteristics of safety climate and safety culture for the purposes of this investigation.

Table 31 Safety Climate vs. Safety Culture	
Safety Climate	**Safety Culture**
Macro scale	Micro scale
Perceptions	Beliefs
Practices/Operations	Values
Policies	Attitudes
Management	
Investigation- quantitative	Investigation- qualitative

From this table one can discern the practical differences between safety climate and safety culture. This distinction is used in the assessment of safety practice at the case institutions.

Differences in Data Collection

One distinction between safety climate and safety culture has been in data collection and analysis. Flin et al. argued that research on safety culture and climate developed differently (74, 101). As described by Flin et al., safety climate research has focused more practical rather than theoretical underpinnings(74). In contrast, safety culture investigations have been qualitative in nature. The data for safety culture studies has been collected through observation and interviews and the results of safety culture studies have mostly been in-depth case studies. In contrast, safety climate research has involved empirical research of the concept over theoretical development. Safety climate data has predominantly been collected by methods such as questionnaires, and analyses have tried to link a positive organizational climate with several outcome measures, including increased production (e.g., Pritchard & Karasick, 1973), and greater job satisfaction (e.g., Schneider, 1975) via Yule (2003) (102). Data analyses have sometimes been quantitative. Table 32 presents quantitative methods used in some Safety Climate studies.

Table 32 Quantitative Methods used in Safety Climate Studies	
Factor Analysis	(Cox and Cox (103)),
Regression	Niskanen (1994a via (102))
T-tests, exploratory factor analysis	(Niskanen (1994b via (68)
Analysis of variance	(Rudmo 1994, Alexander 1995) via (68)

As shown, safety climate investigations are more quantitative and safety culture, more qualitative, although quantitative methods have also been used to evaluate data collected qualitatively. As procedures and policies are important components of safety practice and measurable with quantitative metrics, safety climate measures can be useful in the investigations of academic safety culture. However, qualitative analysis of safety culture is also important and the next section focuses on the safety culture model derived for this investigation using both safety culture and safety climate elements. These distinctions will be explained and utilized in the next section where the construction of the academic safety culture model is described.

SAFETY CULTURE MODEL CREATION

The Academic Safety Culture Model

The illustration in Figure 2 is the Safety Culture Model created for this analysis of academic safety culture. From the safety culture literature, a model was created for this assessment of post-accident safety culture to represent academic safety culture. It was constructed for this investigation specifically to aid in illustrating the relationships between processes, values and culture. The model is based on research on a combination of elements found in the safety culture and laboratory safety literature. The safety culture model is comprised of values and procedures that research has shown to be part of academic safety culture.

Values in the model are principles and beliefs that characterize a safe environment. The procedures in the model are the basic, foundational, "low hanging fruit" in the quest for safety culture. The bases for choosing the values and procedure that are elements of the model are discussed in this sub-section. All the procedures are described and prescribed by the OSHA laboratory standard (104) and Prudent Practices (1).[11]

Safety Culture and the Academic Institution

Within an academic institution, the structure of the safety department and its position in relation to the administration and the science departments is critical to the way safety is practiced. The following model in Figure 11 illustrates the relationships between

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[11] This model was constructed and a draft was shown to several academic EHS staff. Hazardous waste management and disposal and emergency planning were added to the procedures because of this vetting.

structure, processes and culture. This model was constructed by the European Agency for Health at Work (105) from research by Guildemund(106) and Antonsen (81). It shows the critical role that the structure of the organization plays in safety culture. Within this investigation, the structure of the safety department and its relation to the administration and the science departments is included under management commitment to safety.

Academic Safety Culture

In an academic environment the safety practice is influenced by the structure of the university administration. Based on standard safety practices and standard of care, procedures are set up to monitor and maintain regulatory compliance and safety of students. Many times these are guided by the OSHA laboratory standard and Prudent Practices for laboratories. Regulations only address radioactivity and biological materials. Chemical management outside of these areas is generally unregulated until the chemical becomes waste.

This model depicts that both structural and procedural components of organizations contribute to culture which in turn contributes to them. Figure 12 illustrates the relationships between the organizational structure, safety procedures and safety culture.

Figure 11 Academic Safety Culture Model

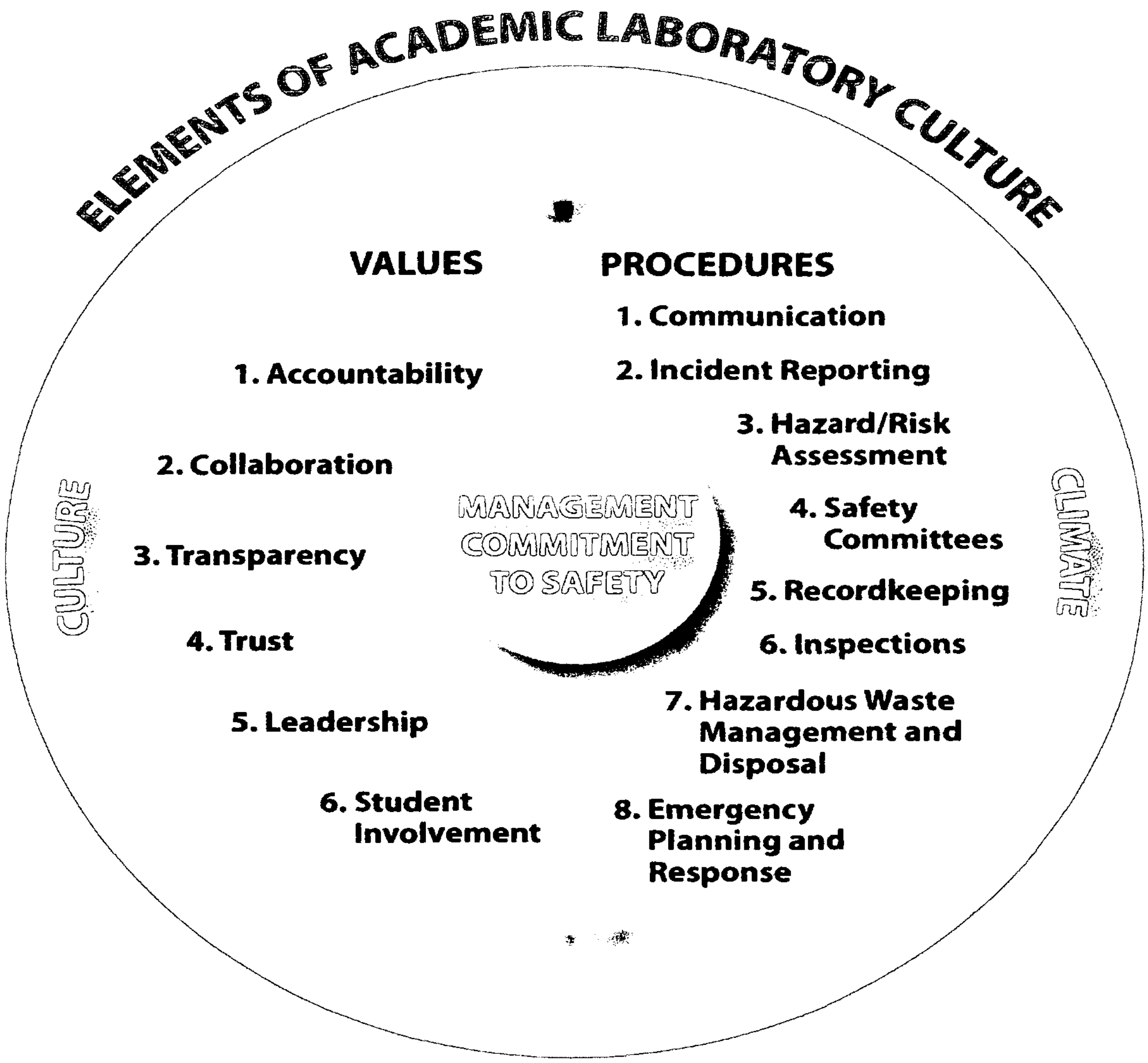
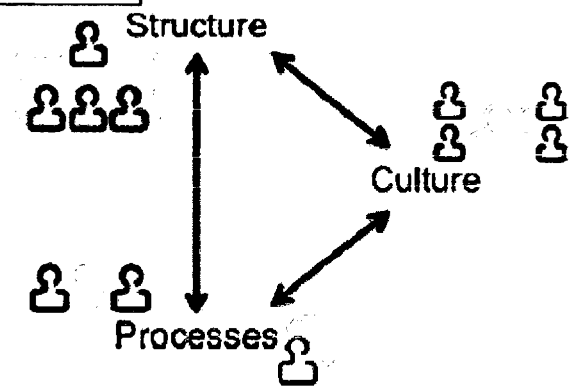


Figure 12 Safety Culture and the Organization



Source: based on Antonsen, 2009, p. 44f.; Guldenmund, 2010, p. 85.

Safety Culture Model Creation

This section describes identification of the elements of the safety culture model and the bases for their inclusion in the model based on the above literature review. In order to derive a core model appropriate for examining accident in academic settings, the safety culture literature was coded by subject area using NVivo, a Qualitative Data Analysis Tool. Coding resulted in 225 subject area nodes which were further consolidated into 20 aggregated nodes. From the sources containing information on frameworks, a subset of articles was identified with frameworks that contained values relevant to academic laboratories. Specific values were identified from these sources. The sources containing these frameworks and the process with which the academic safety culture model was derived is described here.

Identifying an Academic Safety Culture Framework

The safety culture model consists of procedures and values. Based on the distinctions made between safety climate and safety culture in Table 31, the procedures in the model are described as "safety climate" procedures. The values are "safety culture" values. This section derives the safety climate procedures by synthesizing the safety climate and safety culture frameworks, described in several literature sources, and safety guidance documents such as *Prudent Practices in the Laboratory(1)*, and distilling them into a relevant list of elements – procedures and values. Procedures are derived first and values are derived separately following the procedure synthesis.

Derivation of safety climate elements (procedures)

The procedures included in the safety culture model are considered safety climate elements based on the distinction made in Table 30 and shown in Figure 11. The characteristics of safety climate elements are: macro scale, perceptions, practices/operations, policies, management and quantitative investigation. For the sake of this investigation, the macro scale practices and operations attributed to safety climate fit nicely into the procedures considered the bedrock of academic lab safety. Many of the procedures described are the best practice "bread and butter" of academic environmental health and safety practice. They were identified from safety climate literature and safety practice literature. Several have been identified as critical climatic elements of a comprehensive safety culture.

Procedures such shown in Figure 11 are standard conduct for laboratories. They are defined in Table 33. Some of these procedures were described by the NRC(107). The basis for the inclusion of procedures in the model is that they are included in the classic volume Prudent Practices in the Laboratory (2011) and may be quantitatively measured. Inspections, training, recordkeeping, hazardous waste disposal and emergency planning and response are also all part of the OSHA laboratory standard (OSHA). They are included in the model because they are the expected standard procedures according to guidance. Only hazardous waste will not be discussed further in this section. The others will be discussed in the result section. Four procedural elements in the model are not included in the OSHA laboratory standard but are included in the 2011 Prudent Practices are Communication, Incident Reporting, Risk Assessment and Safety Committees. These four elements of the safety culture model plus hazardous waste management and their origins in safety literature are presented in the following section.

Table 33 Safety Climate Procedures

Safety Climate Component	Definition	Sources
Communication	Administrators and PIs share information with students and the academic community. Enables students to ask questions, voice opinions, or report spills without blame. Communications maintain a focus on safety.	*NAS, Guildemund, Havold, NRC*
Incident Reporting	A safety-conscious work environment is maintained where personnel feel free to raise safety concerns without fear of retaliation, intimidation, harassment, or discrimination. A good reporting system allows and encourages students to report safety problems, and it also provides timely and valuable feedback to all students	*Reason, UK HSE, NRC, Eiff*
Risk/Hazard Assessment	Gather information about the chemicals and processes to be used, the chemical and physical hazards associated with them, possible adverse interactions that might occur, and plan for precautions and personal protection required. The process of planning and controlling work activities is implemented so that safety is maintained.	*NAS, US Chemical Safety Board ,U.S. Labor Dept.*
Safety Committees	*"A forum where safety concerns can be raised, information can be distributed to affected parties, and a rough sense of the efficacy of policies and programs can be gained."* The best committees include students and laboratory technicians because they are the hands-on participants in the lab.	*NRC, US Chemical Safety Board , Whitener*
Recordkeeping	Institutions should have a system where they identify labs; register the projects associated with them and the personnel there	*NAS, Guldenmund*

	to make sure that all those pieces are matched, either for providing institutional assurances for grants or just routine recordkeeping that passes through committees.	
Training	Continuous reinforcement of the importance of safety throughout the chemistry educational process is required to instill a strong positive attitude in safety. Should be frequent and task-specific.	*NAS, OSHA. Guldenmund*
Inspection	Inspections safeguard the quality of the institution's laboratory safety program. They should be carried out regularly by qualified individuals using checklists.	*NAS, OSHA*
Hazardous Waste Management and Disposal	Management of laboratory wastes is required by RCRA and is more closely regulated than chemical handling in labs.	*NAS, OSHA, EPA, Guldenmund*
Emergency Planning and Response	The College Opportunity and Affordability Act (COAA)(H.R. 4137-2008) mandates campus safety and disaster readiness plans development.	*NAS, OSHA*

Source: (108)

Description of Safety Climate Procedures

As stated, many of the procedures described are the basics of academic EHS practice and are the minimum achievable in a safety practice. They are generally macro scale elements (Department or University-wide) and can be measured quantitatively. However, they can also be micro-scale (Department or Laboratory) and have qualitative components.

The basis for the inclusion of most procedures in the model is quite simply that they are included in the classic volume Prudent Practices in the Laboratory(1). Four procedural elements are not explicitly included in the OSHA laboratory standard but included in the 2011 Prudent Practices: (Communication, Incident Reporting, Risk Assessment and Safety Committees) are discussed below.

Communication

Communication requires administrators or PIs sharing information with students and enables students to ask questions, voice opinions, or report spills without blame. This is similar in non-academic workplaces. Organizations with a positive safety culture are characterized by "communications founded on mutual trust, and by shared perceptions of the importance of safety"(109). As reported above Whitener et al. (110) argued for open communication as a way of engendering trust. Upward safety communication – the willingness of employees in an organization to share comments regarding safety issues with their superiors (111) is the sign of a developing trusting environment.

Communication must flow up from the students and down from the administration. This, of course is an ideal situation and in many cases the students may be too intimidated to voice fears or concerns in the laboratory. Avenues should be open to encourage discussions and inquiries about safe practices in the lab. Whether or not communication exists in an academic environment is easy to measure. However, the quality and transparency of that communication is harder to ascertain.

Incident Reporting

Incident reporting was included in the lists of Reason, (85) the NRC (107) and the UK HSE. Eiff (1999) wrote that "One of the foundations of a true safety culture is that it is a reporting culture" (112) pg. 17). A good reporting system allows and encourages students to report safety problems, and it also provides timely and valuable feedback to all students (95). An effective and systematic reporting system is the key to identifying the weakness and vulnerability of safety management before an accident occurs. The willingness and ability of an organization to proactively learn and adapt its operations based on incidents and near misses before an accident occurs is critical to improving safety. The importance of incidence reporting was reiterated by the CSB's findings and recommendations from its investigation of the 2010 laboratory explosion incident at Texas Tech University (3).

An organization with a good safety culture should have a formal reporting system in place and one that is actually used comfortably by students and employees. Another important element of a good safety culture is "the free and uninhibited reporting of safety issues that come to the attention of students and lab personnel during the course of their daily activities" (112), pg.19. This should include near misses, as well. To promote this, it is important to ensure that students will not experience reprisals or negative outcomes as a result of this policy, as well as to have a structured feedback system to inform the students that their suggestions or concerns have been reviewed and what kind of action will be taken to solve the problems. Reason (85) argues that normalization of these values would occur under the conditions of a 'reporting culture' – in which students feel free to report their errors and near misses to PIs without unjust punishment.

Policies promoting blameless incident reporting to encourage learning from mistakes can be established but the actual comfort of students to voice concerns and document near misses is more difficult to measure.

Risk and Hazard Assessment

Laboratory safety guidance and safety professionals agree that risk assessment in a critical component for safe handling of chemicals in the laboratory (1, 109). "Institutions should ensure that research-specific hazards are evaluated and mitigated"(3).
Risk Assessment needs to be part of the process the scientists engage in every day in the lab. It requires hazard assessment and planning. It involves gathering information about the chemicals and processes to be used, the chemical and physical hazards associated with them, possible adverse interactions that might occur, and planning for precautions and personal protection required. Risk assessment allows members of an organization to analyze the frequency and expected outcomes from potential incidents. Using a risk assessment, the organization can determine if it is appropriately emphasizing the most significant risks and/or how it might mitigate them (3).

The following is argued by Michael Wright of the United Steelworkers "A positive safety culture focuses on hazard identification and risk assessment, using formal tools, but also through a constant "situational awareness. The way to build the latter is to involve students and lab workers -- the people most exposed to the risk – in that formal process of finding the hazards and assessing and addressing the risk. That's also the best method of education" (113). Risk Assessment needs to be part of the process the scientists engage in every day in the lab. Risks of procedures may be underestimated because this step is missed or because of inadequate chemical information available.

Box 4.1 in the 2011 Prudent Practices edition provides guidance on conducting a risk assessment in the laboratory. The steps to carry out a risk assessment in a laboratory are as follows:

1. ***Identify chemicals to be used and circumstances of use.*** This step requires identification of the chemicals involved in the experiment, determination of the amounts to be used and the process as to how they will be used.

2. ***Consult sources of information.*** Laboratory researchers need guidance documents to help manage hazardous chemicals that are unique to their research environments.(114).This step could be seeking sources to better understand the procedures and handling of the chemicals. Standard sources are MSDSs which are not always helpful (48). An MSDS for each chemical used is required by OSHA to be available in the lab. Online sources of chemical information are available and often more useful. (See Weil, paper 2). Depending on the laboratory personnel's level of experience and the degree of potential hazard associated with the proposed experiment, obtain the assistance of supervisors and safety professionals before proceeding with risk assessment (1).

3. ***Evaluate toxicity.*** It is important to understand the toxicity of the chemicals that will be used. Especially important are whether they are acutely toxic, are sensitizers, are irritants, or are carcinogenic or teratogenic.

4. ***Consider possible exposure routes.*** Possible exposure routes are inhalation, dermal absorption, ingestion and injection.

5. ***Evaluate quantitative toxicity information.*** Particularly hazardous substances, are defined as those with a lethal dose 50 value (LD-50), less than 50 milligrams per kilogram, which is the international convention of breakpoint between moderately hazardous or moderately toxic and highly toxic (48).

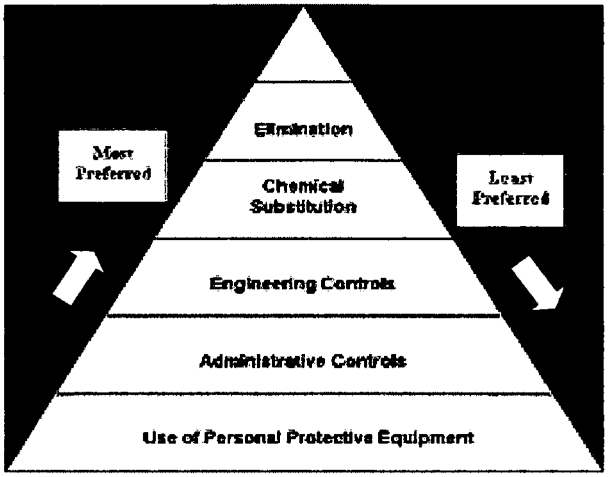
6. ***Select appropriate procedures to minimize exposure.*** Use basic prudent practices for handling chemicals but consult literature and experts for specific hazards that require special handling like pyrophoric chemicals, and explosives. Hazard mitigation is the process of eliminating or reducing the frequency of a risk, the potential consequences of a risk, or both. A common method used in academic laboratories to mitigate hazards is the use of personal protective equipment (PPE). (3) However, as shown in this diagram of the hierarchy of controls, PPE is the least preferred method of mitigation. Nonetheless, in most academic laboratories, PPE plus engineering controls (e.g., fume hoods) and possibly administrative controls are common practice. Traditionally, a hierarchy of controls has been used as a means of determining how to implement feasible and effective controls. Figure 4 depicts the hierarchy of controls.

7. ***Prepare for contingencies.*** Know the signs and symptoms of exposure to the chemicals to be used in the proposed experiment. Note appropriate measures to be taken in the event of exposure or accidental release of any of the chemicals, including first aid or containment actions. (1)

A risk assessment policy can be established but its successful implementation is difficult to maintain without PI commitment to planning and safety.

The control methods at the top of the list are potentially more effective and protective than those at the bottom. Following the hierarchy normally leads to the implementation of inherently safer systems, ones where the risk of illness or injury has been substantially reduced (115).

Figure 13 Hierarchy of Controls



Safety Committees

Safety committees are a vehicle that can promote communication, transparency and trust by providing a forum to discuss near misses and incidents so that a wide swath of people learn and contribute to the learning process. In some institutions there are different layers of committees – school wide, department wide, administrative (3). The best committees include students and laboratory technicians because they are the hands-on participants in the lab.

Prudent Practices includes the following recommendation for instituting safety committees.

> *"... achieving a safe laboratory environment is a cooperative endeavor between management, EHS personnel, and laboratory personnel. Regulations, policies, and plans will never cover every contingency, and it is important for these different groups to communicate with each other to ensure that new situations can be handled appropriately. One way to ensure that the needs of all groups are being met is by creating safety committees consisting of representatives from each part of an organization. In this forum, safety concerns can be raised, information can be distributed to affected parties, and a rough sense of the efficacy of policies and programs can be gained." ((1) p. 12)*

Wu et al. (116) studied safety culture in Korean Universities and tested the hypothesis that there is no difference in safety climate between universities with and without a safety committee. The result revealed that management commitment to safety, the employee's safety commitment, and emergency response had a significant impact on perceived risk. When the impact of "safety committee," was added in to the equation, management safety commitment, employee's safety commitment, and emergency response in universities with a safety committee were higher than those without a safety committee. Whether safety committees exist at a university can be measured quantitatively. The quality of interactions within the committees is more difficult to measure. Safety committees can be university-wide, or by department and can have participation from faculty and staff only or include students.

Hazardous Waste Management and Disposal

Hazardous waste management and disposal are areas that are more closely regulated than chemical handling in the laboratory. According the RCRA, the definition of hazardous waste is given as: A chemical waste is considered hazardous if it is either listed on one of the lists found in Federal or State regulations or if it exhibits one or more of the four following characteristics (117):

Ignitable - ignitable wastes generally are liquids with a flash point below 60°C or 140°F (however, just because a material has a higher flash point, it still cannot be drain disposed).

Corrosive - corrosive wastes are generally aqueous wastes with a pH less than or equal to two (2) or greater than or equal to 12.5

Reactive - reactive wastes are those wastes that are unstable, explosive, and capable of detonation or react violently with water.

Toxic - a chemical that poses a hazard to health or the environment (this can be a gray area).

Determining if a waste is a hazardous waste can be difficult, especially if the container has not been properly labeled and chemicals in use have not been inventoried. In the absence of this information is good policy to assume that all chemicals are hazardous and must be managed through the EHS. Strict sewer, air emissions and landfill regulations require that hazardous waste is not poured down the drain, evaporated in fume hoods or disposed of in the normal trash.

Safety Culture Values

The derivations of the safety culture values included in the model are described in this section. The aims of the values extracted are those associated with a just, learning and collaborative safety culture. Just as the safety climate procedures described above were gleaned from the safety climate and safety practice literature, safety culture values applicable to academic environments were mined from the safety culture literature. Safety culture elements are less easy to measure quantitatively and are often on a micro-scale or within a laboratory or department. The safety culture values were derived from several sources referenced in Table 34.

Table 6 summarizes the common themes from several safety culture articles. The values represent a synthesis of values from the literature. The following section describes each of the values in the model. This list of values distilled in Table 34 correspond to the categories of factors found in a similar review conducted by Flin et al. (74).

Table 34 Safety Culture Values

Safety Culture Component	Definition	Sources
A. Management Commitment to Safety:	Management and employee commitment to safety is in the center of the model because in academic safety culture, this is what holds the values and procedures together. Management commitment has three components : resources, administration support, and organizational structure	Havold, HSE, NRC, Guldenmund
B. PI Responsibility/ Oversight/ Sanctions/Penalties	All individuals take personal responsibility for safety. PI's take responsibility for safety in their laboratory. Strong sanctions and penalties require clear consequences for non-compliance and authority to enforce them.	NRC, NAS, Guldenmund, US Chem.Safety Board
C. Collaboration	Scientific collaboration increases scientific productivity and collaboration with EHS enhances safety practice.	NAS, US Chem Safety Board, Whitener
D. Transparency	Transparency in this type of safety system requires the active participation from the workforce to report near misses, and employee involvement in how safety is managed.	Reason, Havold, HSE, NRC,
E.. Trust	Trust and respect permeate the organization.	Reason, NRC, Kath et al.
F. Leadership	Leaders demonstrate a commitment to safety in their decisions and behaviors.	NRC, Krump, Wu
G. Student Involvement	Organizations with a "good" safety culture empower their employees and ensure that employees clearly understand their critical role in promoting safety.	NRC,Antonsen

Source: (108)

Safety culture model values

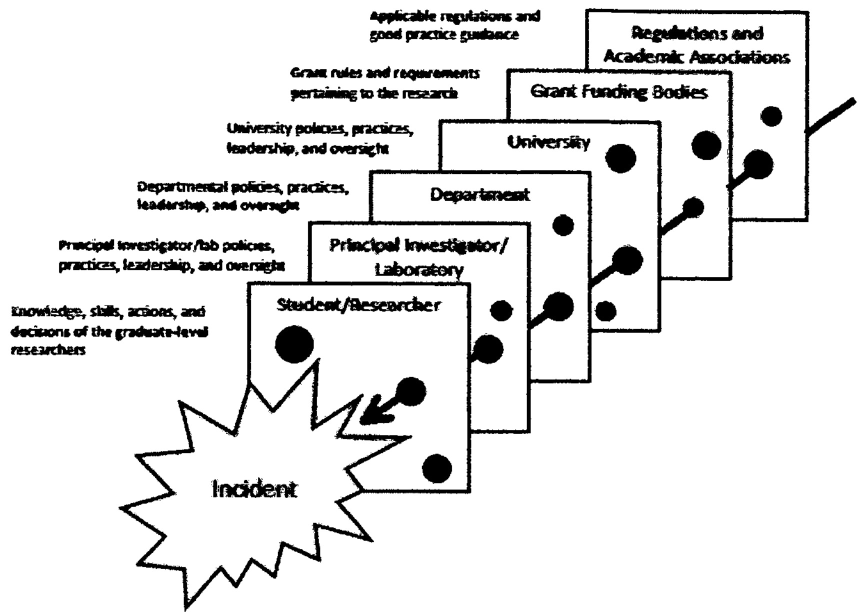
Managerial Commitment to Safety

An organization's upper-level management is widely recognized as playing a critical role in promoting organizational safety culture (61, 67, 74, 95, 101, 102, 118). Management and employee commitment to safety is in the center of the model because in academic safety culture, this is what holds the values and procedures together. This is also true in industry. Values emanate from management. Good intentions are rudderless without the backup of an overriding, pervasive commitment to safety. The critical nature of this value is supported in the safety culture literature. Research has shown that supervisors' and coworkers' practices are likely to constitute the most powerful antecedents of role behavior in work groups, with the organization-level context providing the antecedent (119).

Through participation in the day to day operations, both upper- and middle-level management communicate to their employees an attitude of concern for safety that subsequently influences the degree to which employees comply with operating rules and with safe operating practices (112). Within the context of safety culture, "management involvement" refers to the extent to which both upper- and middle-level managers get personally involved in critical safety activities within the organization. Management involvement in safety, therefore, is reflected, by managers' presence and contribution to safety seminars and training, their active oversight of safety critical operations, their ability to "stay in touch" with the risks involved in everyday operations and the extent to which there is good communications about safety issues, both up and down the organizational hierarchy (95). Two contributory components are resources and administration support of programs in terms of funding and personnel and programs.

Another contributory aspect of management is the structure of the organization. The structure of the organization plays an important role in safety culture. In an academic institution, this is where the EHS department is the administration in relation to the science departments. In this type of environment, there are many levels of management. This is shown in the Chemical Safety Board's adaption of Reason's 1997 Swiss cheese model, as shown in Figure 14. Reason created the Swiss cheese model to show the layers of defenses, barriers, and safeguards in place in an institution to protect potential victims from hazards (85). Holes in the layers represent how the layers of defense could be penetrated. The CSB used the model to illustrate the perfect alignment of errors or lack of oversight that lead to the TTU accident. It also serves to illustrate the complicated nature of academic administration. The element of organizational structure is critical and how it is implemented so that it is felt by students is an important factor in safety culture.

Figure 14 Examining a Laboratory Incident using Reason's Swiss Cheese Model of Accident Causation



PI Responsibility/Oversight

In an academic institution, as shown in this (CSB's) version of Reason's 1997 Swiss Cheese model, the first line of supervision is often the PI because PIs are responsible for the safety of the students in their laboratories. Many times this responsibility is abdicated in favor of pursuing research, of fulfilling teaching and administrative duties. "In many cases, academic freedom is more important than safety," Jim Kaufman, president of the Laboratory Safety Institute in Natick, Massachusetts[12] was quoted as saying. (120). Failure of the institution to demand that faculty take responsibility is a problem. In academic institution where there is no accountability of PI's, there is a lack of trust and the transparency fails because critical safety or procedural information is not provided to

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[12] Dr. James Kaufman is a safety consultant and the proprietor of the Laboratory Safety Institute which is a non-profit organization that provides safety training throughout the world.

the students. However, PI's bring money into the University and the University does not want to lose the money that the PI's bring in so it is reluctant to put pressure on them. Responsible PIs make a difference in safety. "It doesn't matter how many EHS staff there are, they can't be in the labs all the time, especially at a large institution with hundreds or even thousands of labs" (121). In industry, there are supervisors in the lab, supervisors supervising those supervisors, etc. Employees in these companies are professional adults with a vested interest in keeping their jobs. There is incentive to follow the rules. Universities have a mix of ages, of experience and the tenure of students is short which leads to a difference in incentives for accountability in academic situations. When an accident or incident occurs in a lab resulting in an injury or damaged property it is considered an accident and the PI is generally not held responsible. This situation differs from business environments and even in other parts of the University where performance reviews include accountability (121).

A different view of the PI's behavior was provided by Neal Langerman[13] "The motivation for PIs comes down to three things: 1.funding, 2. peer recognition, and 3. research real estate" (i.e., laboratory space). Langerman argues that there is no responsibility or accountability for anything else (121). The modification of these incentives to promote PI accountability requires commitment to safety throughout the

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[13] Dr. Neal Langerman is a safety consultant and the owner of *ADVANCED CHEMICAL SAFETY*, which is specifically dedicated to the prevention of workplace injuries, illnesses and environmental damage. He is the author of the book "Precautionary Labels for Chemical Containers", 1994 and a peer reviewed article, "Material Safety Data Sheets: Who Uses Them?" which was published in the American Chemical Society publication "Chemical Health and Safety" in 1995.

layers of university management. This includes department chairs, provosts, and academic vice presidents. This is illustrated in the Swiss Cheese Model.

Collaboration

Research has shown that scientific collaboration increases scientific productivity (122) (123). Modern laboratory spaces are being designed in an open manner to encourage collaboration between researchers (1). Open lab spaces facilitate cooperation and collaboration. This works to encourage collaboration on safety issues as well. There are useful examples of collaboration on safety issues, such as an MIT peer-review process with the National University of Singapore, in which each institution audited the health and safety programs of the other. If asked, researchers are usually more than happy to make safety policies available or send them out to others (124).

Transparency

In the context of academic laboratories, transparency involves open communication that flows both down from the Principal Investigator (PI) and up from the students. In this context it is often difficult to employ. But as the literature argues, it is a critical element of safety culture. Westrum (125) claimed that "the most critical issue for organizational safety is the flow of information". Reason (85) defined safety culture as consisting of constellations of practices, most importantly, concerning reporting and learning. A safety culture, he argues, is both a reporting culture and a learning culture. The elements "reporting and learning" require transparency.

Kath et al. in their discussion of open communication argued that transparency engenders trust in the workplace and creates a safety culture where people are confident enough to question and take precautions (126). Whitener et al. (110) found that managers, who are accurate in their communication, provide adequate explanations, and keep the lines of communication open encourage trust among their employees. Additionally, Shockley-Zalabak (127) found that accuracy of information, explanations for decisions, and openness are three aspects of communication that are positively related to trust. Similarly, (128) found that open communication predicts increased levels of trust. These findings indicated that in many environments, including the academic environment, the availability of reliable of safety information is critical to safety practice and culture.

Trust

Kath and Magley (126) argue that organizational trust is a key element of safety culture that impacts organizational outcomes. Burns, Mearns and McGeorge (129) argued that trust plays a central role in models of safety culture and proposed a model based on explicit and implicit trust. Research has found that mutual trust promotes safety through participation and social norms (130). Trust is needed, especially to encourage beliefs that people are trying their best, even when they have to report accidents and near-miss incidents which all too easily look like failures of individuals (108, 131). Researchers found that trust in management, together with safety culture, predicted safety knowledge, safety motivation and safety behavior, as well as a lower rate of safety incidents. Organizational factors such as open communication, increased decision authority, information sharing, power sharing, and the sharing of feelings/perceptions correspond with trust (131).

Leadership

Wu et al. (116), in a study of safety culture at universities in Korea, found that there are two paths that will affect safety performance. One goes from safety leadership, through safety culture, to safety performance, while the other goes from safety leadership to safety performance. This finding was echoed by a nuclear regulatory examination of safety culture that found that during the external benchmarking process, agencies and organizations that focused on safety culture described having strong leaders throughout the organization who modeled safety culture behaviors and were engaged and present (107).

An editorial in the journal *Nature* following an accident at Yale University where an undergraduate student died in 2011 emphasized the importance of leadership for safety in the academic environment. "Leaders of research projects must take responsibility for the safety of scientists doing the work, and must start to work with safety officers, rather than endure them. In turn, senior figures in academic departments must realize that practices and priorities have changed since their earlier days, and be willing to shut down laboratories until any potentially dangerous working practices are improved" (120).

Within the safety culture, there is a need for leadership alignment, throughout the layers of management, to be established. Leadership alignment occurs when there is consensus for the safety culture implementation strategy at various levels within the organization from lab groups to departments to upper management. Leaders must gather student perceptions to identify true alignment, assumed alignment, forced alignment, or skewed alignment around the direction and implementation of the safety culture change process (119).

Student involvement

The hierarchical rank of students in academic laboratories in relation to PIs and post doctoral students can make it difficult for them to voice concerns about safety. Organizations with a "good" safety culture empower their employees and ensure that employees clearly understand their critical role in promoting safety. This requires a type of empowerment. This kind of empowerment refers to an individual's perceptions or attitudes as a result of a delegation of authority or responsibility by upper-level management. An empowered attitude can lead to increased motivation to "make a difference," to go beyond the call of duty for organizational safety and take responsibility for ensuring safe operations (132). Within the context of academic safety culture, student empowerment means that students have a substantial voice in safety decisions, have the leverage to initiate and achieve safety improvements, hold themselves and others accountable for their actions, and take pride in the safety record of their laboratory (95).

Student involvement at every stage can make a difference in attitudes towards safety parts of an organization are at different levels at any one time. It is important for organizations to diagnose the status of individual elements of the safety culture before attempting to improve the safety culture. This includes whether students have a role in safety teams or committees and whether there are avenues for investigation of safer handling and precaution that can be undertaken without criticism or ridicule.

Several studies have shown that small work groups rather than organizations have greater influence in the socialization of new members (133) and they serve as the main source in satisfying the need for belonging, support and encouragement. Thus, individuals typically feel closer to their work groups than to their organizations (63). In an academic situation, this can apply to laboratories or teams within laboratories, indicating the importance of student involvement.

Antonsen has written that power relationships should be considered in safety culture investigations (134). The place where power inequality is most apparent is in relations between students and PIs. It is this inequality that makes it difficult for students to voice their concerns about safety. Safety teams are one example of how students can become involved in safety practice in an academic lab. An experiment was conducted at Seattle University with safety teams where the teams prepared pre-lab hazard assessments, where students were actively engaged in finding, organizing, and presenting safety information. Students also led discussions on safe practices during procedures and served as an extra set of eyes for identifying safety issues (135). This led to a higher safety consciousness and increase in safety behavior. The researchers also found that students in safety teams performed significantly better than 30% of traditional organic chemistry and 50% better than general chemistry students on safety assessment questions. They also found that the safety team approach transformed their academic labs by engaging students in the critical evaluation of lab practices and by increasing their attentiveness to laboratory safety. They viewed this as increasing the tone of professionalism in the labs (135).

Summary

The values and procedures described above are associated with a healthy safety culture and are fairly straightforward. The beliefs underlying them are more complex. Taken together the values and procedures form a safety culture of trust and of transparency. However, they are dependent on management commitment to safety in order to promote safety in the workplace (136).

The Prism Safety Culture Guide[14] reported in 2003 that "Safety culture is now generally accepted as a "good thing" to have, and there is a growing consensus about the main features of a positive safety culture" (82, 136). Subsequent literature has argued about the specific components but has generally agreed on a core subset. The core subset has been modified to fit the academic laboratory environment. In the next section describes the method used to collect data from the cases to be evaluated. The results of the evaluation follow the discussion of the methodology.

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[14] The Prism Safety Culture Application guide was prepared as part of the activities of the EU-funded PRISM project, which concerns human and organizational factors which affect health and safety in the European process industries.

DATA COLLECTION AND METHODS

Problem Identification

This project is an assessment of how accidents in academic laboratories act as catalysts for changes in chemical management and health and safety practice in colleges and universities. The lens through which this question is investigated is safety culture. This section identifies and describes the methods used to perform the assessment.

Method Selection

An academic approach, as described by Guildemund (2010) was used to perform this assessment. The investigation consisted of fieldwork, ethnographical-inspired methods (including document analysis), observations, interviews, and correspondence. The use of ethnographic research methods for assessment of safety culture is shown in recent research by Antonsen (2009) (81) and Guldenmund (2010) (137). A comparative case study is used as the method for this investigation. The case study method is the preferred method of researching "how" questions when the investigator has little control over events and when the focus is on contemporary phenomena within some real-life context (138). In addition, there is precedence for the use of case studies in safety culture investigations.

This investigation was conducted in the manner of a medical checkup. A checklist of "safety culture" and "safety climate" components and criteria for good achievement was derived and the cases were compared to that list.

Questionnaire

In order to assess the Safety Culture model, information derived from the interviews conducted at each institution was used to document each element of the model. The questions were aimed at investigating the changes that had occurred at the institution since the accident and to assess the safety culture of the institution. Because investigation was to involve interviewing stakeholders at institutions where accidents, including fatalities in two cases, had occurred, an application was submitted to the UMASS Lowell Institutional Review Board. The Institutional Review Board required copies of the questions, and required that letters be written by officers at each institution giving me permission to conduct interviews at their institution and their agreement to cooperate.

A sample questionnaire is included as Appendix C.

Interviews

Interviews were carried out at each institution with several stakeholders. The description of this process and list of stakeholders interviewed is included in Appendix D.

Data Analysis

Using the elements of the safety culture model, NVivo was employed to assist with the analysis of the accident specific information. The subject nodes used in the literature review were consolidated and aggregated roughly into the categories of the safety culture model. The interviews and materials from each accident source were categorized using this same framework for purposes of analysis.

From this a matrix analysis was conducted using NVivo. This included searches for the instances where the safety culture element had been coded in the accident source material. This was supplemented by performing word queries for key safety culture words such as "accountability", "training", "trust", etc. In this way, each time that these words were mentioned in the interviews and each time a safety culture topic in the interviews was located.

From this exercise a matrix of safety culture elements was compiled and a qualitative assessment of each institution's safety culture conducted based on their coverage of each element. A table was constructed with safety culture elements on the y axis and the three schools on the x axis. Quotes and information from the literature were included in each cell- based on the interviews and articles about the accidents. This is the basis for the analysis of the cases.

RESULTS - EVALUATION OF CASES

In this section the safety practices of the three cases are evaluated through the lens of the safety culture model. The assessment is accomplished by examining how each university performed the safety culture elements. The section is organized into the procedure assessment and the value assessment. That is, first each procedure is briefly described in the context of academic safety culture and the practice of each school is summarized. The list of procedures is presented in Table 33. A procedure assessment summary table is presented at the end of the procedure assessment section. That is followed by a value assessment which is organized similarly. The last of values is in Table 34. A value summary table is presented at the end of the value assessment. Finally, an overall assessment table is presented summarizing and interpreting the results of the safety culture assessment.

Safety Climate Procedure Assessment

Safety Climate procedures included in the safety culture model are best practices and should be standard conduct for academic laboratories (107). The basis for the inclusion of procedures in the model is that they are included in Prudent Practices in the Laboratory (2011), the standard guidance document for EHS practice. Their classification as safety climate elements means that they are macro-scale elements, and their success is partially quantifiable.

The last five procedures are also all part of the OSHA laboratory standard (104). All of these procedures are included in the safety climate portion of the model because they are the expected standard laboratory procedures according to guidance. Many of the questions asked of the interviewees at each of the institutions pertained to conduct of these procedures. A summary of the procedural assessment is provided in Table 10 following the nine sections.

Communication

Communication is an important procedure that facilitates transparency, education and compliance. Open communication is, of course, an ideal situation. In that situation, information must flow up from the students and down and outward from the administration. In reality, students may be intimidated to speak up about fears or concerns in the laboratory. Avenues should be open to encourage discussions and inquiries about safe practices in the lab.

Two components of safety communication are examined herein – external and internal. External communication is considered information that is available to the public including the EHS community. Internal communication is the information available to students and staff at the university.

External Communication

A criterion for good external communication is helpful, collegial communication that promotes best and safe practices and contributes to safety practice in the academic arena outside of the university. A special case of external communication is the provision of information about an accident when the accident occurs. Since accidents are the subject of this investigation, external communication focusing on that will be discussed.

UCLA

UCLA has been very open about the accident and about the actions it is taking to correct the deficiencies identified by Cal OSHA that caused the accident. EHS Director Gibson has given many presentations to many groups including CSHEMA and ACS, talking about what UCLA is doing to improve oversight, instituting a PPE policy (UCLA Policy 905: Research Laboratory Personal Safety and Protective Equipment was published in February 2010), improving training and health and safety practice in general. UCLA has made these presentations and safety videos available to the public[15]. The value in doing this is in gathering and sharing ideas for program improvement and innovation with other EHS professionals. This policy also puts UCLA at the forefront of the quest for improved laboratory safety. Other universities across the country such as Yale and UMASS Lowell are measuring their practices such as training and inspections against UCLA's improvements in safety practice (139-141). This comparison is on the basis of statistics compiled by UCLA and presented at meetings regarding their "improved" programs.

Recently, dozens of universities, regulatory agencies, private research operations and trade organizations have sought information or requested permission to use various

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[15] The UCLA EHS Website has a list of eight safety videos available on YouTube and I-Tunes U, two online resources publically available. Topics include Fire Safety in the Lab, Pyrophoric Liquid Safety, and To Be Safe or Not To Be – specifically aimed at Undergraduate Science students. There is also an extensive list of DVDs and safety videos available to borrow from the EHS Safety Video Library.

elements of UCLA's lab-safety programs, including a laboratory-hazard assessment tool (LHAT) and lab-safety training videos produced by Gibson's EHS department after the accident. "To have broad oversight over lab safety in a decentralized and complex university environment is a huge challenge," says David Acker, associate director of safety and health programs at Auburn University. Mr. Acker requested permission to use the lab-safety training videos. "Being able to offer the information and high-quality resources that UCLA has is very helpful" (34).

Northwestern

Two aspects of external communication at NU are worth noting. The PIs supervising the laboratory where the accident occurred communicated safety-relevant information about the accident to the chemistry community quickly. A letter documenting the accident was published in Chemical and Engineering News (14). The PIs also responded to follow-up questions on *C&EN's* safety blog. They also wrote letters to other researchers known to be using the procedure, included warnings in published papers and indicated that they had discontinued the procedure (14, 44). This kind of action is notable.

Another noteworthy aspect of external communication is the NU ORS Research Safety Newsletter. The newsletter is published quarterly and contains information about procedures, training, chemicals of interest, staff resources. This newsletter has won an award from the College Safety Health and Environmental Management Association (CSHEMA) for best newsletter.

Dartmouth

Karen Wetterhan's accident made national headlines at the time of her death in 1997 (NYT, June 11, 1997, LA Times, June 12, 1997, Associated Press, 03/28/97). Following the accident, the circumstances of Dr. Wetterhahn's accident were made known through articles in professional journals and scientific magazines. Her death shocked not only the entire chemistry department at Dartmouth and the academic safety community, but even regulatory agencies, as the accidental exposure occurred despite having taken all required measures known at that time. Articles were written about toxicity of dimethylmercury and inadequacy of MSDS and lack of protection in generic rubber gloves by Michael Blayney and other colleagues (55). As a result of the accident, OSHA revised the Safety Hazard Information Bulletin on Dimethylmercury (56).

Internal Communication

Good internal communication must flow up from the students and down from the administration. Students should not be intimidated to speak up about fears or concerns in the laboratory. Avenues should be open to encourage discussions and inquiries about safe practices in the lab.

UCLA

Information about the accident is available to the university community as well as the public. Much more information about safety procedures is available from EHS on their website than previously was available (142). All students and staff (including PIs) are required to be retrained. Videos have been created and made available about procedures for handling various hazardous materials (10). This is evidence of downward and outward communication. However no information was obtained from any source on upwards communication.

Northwestern

The NU ORS website is very informative. Students use the new Chemistry Safety Officer (Nick Waddell) as a sounding board for chemistry student questions and concerns about procedures and chemicals. Mr. Waddell spoke about starting a wiki site for students to document solutions and procedural information (42).

Dartmouth

EHS provides general safety and emergency information on flip charts given to each student at orientation. These include, information on gloves, eye and face protection, safety information from case studies (It happened here at Dartmouth…), contact information for emergencies. Little information obtained on upwards communication but students reported feeling safe during laboratory procedures (143).

Incident Reporting

Though incident reporting is a procedure, the institution of a policy promoting it requires a "reporting culture" as defined by Reason (85). An organization with a good safety culture should have a formal reporting system in place and one that is actually used comfortably by students and employees. An important element of a good safety culture is "the free and uninhibited reporting of safety issues that come to the attention of students and lab personnel during the course of their daily activities" (112), pg.19. To promote this, it is important to ensure that students will not experience reprisals or negative outcomes as a result of this policy, as well as to have a structured feedback system to inform the students that their suggestions or concerns have been reviewed and what kind of action will be taken to solve the problems. Reason (85) argued that normalization of these values would occur under the conditions of a 'reporting culture' – in which students feel free to report their errors and near misses to PIs without unjust punishment. Best practice criteria for incidence reporting include a safety culture criterion: a non-judgmental encouragement to report incidents; and a safety climate criterion: a formal mechanism for reporting and discussing incidents.

UCLA

UCLA has standardized inspection reports and specified procedures for reporting incidents. Prompt reporting of laboratory accidents and injuries to Risk Management and EH&S is listed on the Laboratory Duties and Responsibilities for PIs and supervisors on the EHS website. Serious injuries MUST be reported to EH&S within 8 hours of the incident.

Northwestern

NU has standard procedures for reporting incidents. An incident report form must be delivered to the Office for Research Safety (ORS) within five days of the incident (37). Reports are reviewed by the Chemical and Biological Safety Committee, the Radiation Safety Committee, or the Laser Safety Committee. ORS reported that researchers feel comfortable reporting near misses (41), especially with the addition of the chemistry safety officer. The Assistant Director of ORS (Markus Schaufele) wrote: "I think our intent in the safety department is to make researchers comfortable reporting near misses. It is an ideal though that is not always translated into practice" (144). An NU chemistry graduate student also expressed willingness to report minor mishaps (145).

Dartmouth

A formal program to report or discuss near misses or accidents is not apparent from materials on the Dartmouth EHS website, nor on the flipcharts provided to students. However, according to Michael Blayney, Dartmouth students are actively encouraged to report. "Dartmouth has a non-judgmental approach. Because of this they know that people will work to help, not criticize" (145, 146). If true, this could create an atmosphere where students feel comfortable reporting.

Risk/Hazard Assessment

Safety culture means a focus on hazard identification and risk assessment, using formal tools, but also through a constant situational awareness(3). Risk Assessment needs to be part of the process the scientists engage in every day in the lab. The rationale for doing hazard assessments is that many times researchers can't control all the parameters that need to be the same every time to get the same result. Nick Waddell, the NU Chemistry Safety Officer reiterated this in his statement, "In chemistry there's still so much that you can't control, a little impurity somewhere. You may use a different piece of glassware. The timing may be different and concentrations may be different" (42). The steps in a risk assessment process were provided in the previous section. For risk assessment to be done effectively the researchers in the laboratory need to have time and resources for planning the procedure and taking into account and preparing for anticipated hazards associated with the chemicals. EHS offices have different needs for risk assessment planning – they need to know where the hazards are on campus and what personal protection equipment (PPE) might be needed. This is different from personnel in the labs understanding the risks they face when attempting an experiment. Both are important for overall lab safety. One is macro scale and one is micro scale. Information from the cases on both is presented where available.

UCLA

In March 2009, EHS improved macro scale risk assessment by issuing the Laboratory Hazard Assessment Tool (LHAT), to assist PIs and lab managers in identifying hazards and quantifying risk levels and protective measures needed based on the chemicals and equipment they use in their laboratories. The tool, which is online, and keeps records, allegedly must be completed by each lab and submitted to EHS annually, as well as updated whenever there is a significant change in activities (34). However, this program is voluntary and current information provided by UCLA is that of 1,065 active PIs, 772 of them have completed the LHAT. A total of 5,554 people have been verified to have had PPE training through the LHAT (147).

The LHAT is UCLA's policy level attempt to institute a form of hazard assessment but does not represent what actually may go on in the labs to prepare for actual specific procedures. It is voluntary so there is no requirement to use it to do actual micro-scale risk assessment planning.

Northwestern

NU practices both macro and micro-scale risk assessment planning. For macro scale, ORS developed the Integrated Safety Information System (ISIS). ISIS is the on-line web application by which PIs submit applications and registrations for review. ISIS also builds a laboratory's Safety Profile and serves as an educational resource for all laboratory workers (148). ISIS is the means by which any investigator can submit any required application or registration. "So if someone wants to use radioactive materials, they must submit their registration, and apply through ISIS. This includes Recombinant DNA, Human gene transfer. That's all submitted through ISIS. In some cases ORS has automated the committee review processes within ISIS itself " (41).

At the micro-scale, NU laboratories have begun to practice pre-planning hazard assessment since the accident. This is at the individual lab level. The following information was obtained from the interview with ORS staff: Pre-planning hazard assessment was brought into the chemistry department by Nick Waddell. That has been one of the biggest corrections that NU ORS has implemented (41). ORS feels that it is an important safety resource to do the safety research before starting something. It is also the means by which they will go in and do the hazardous preparation work and document the hazard assessment for PPE (42).

Dartmouth

Information from Dartmouth found Macro scale and a hint of micro-scale risk assessment. Michael Blayney has said that "risk assessment can't be done by a safety function. It can't be separated from the research. It needs to be part and parcel of the process the scientists engage in every day to do their own risk assessments" (48). The need for a thorough risk assessment was learned in the experience with Karen Wetterhahn's risk assessment of the hazards associated with dimethylmercury. In retrospect after the accident, Dr Blayney and Dr. Wetterhan's chemistry colleagues tried to understand how the risk assessment she performed led her to do everything right but the outcome went horribly wrong. This was due to the limits of knowledge of toxicity of dimethylmercury. This accident caused a rethinking of the boundaries between safety and risk in the minds of many at the time (59).

As with UCLA, macro-scale hazard assessment for labs at Dartmouth is tied to an information system. Though, because of the size of the institution compared to UCLA, it is on a much smaller scale. Michael Blayney explained how administrative level risk assessment is done at Dartmouth for an individual lab (50).

> *We'll register a principle investigator ... We gather some basic information about their biological work, their chemical work, potentially the radiological work... The work is adequately represented; the individuals working in the lab are named. That's tied to the name directory for the college, and which prerequisites, including introductory laboratory safety, hazardous waste management ... are applicable. To actually look at each project would be, ... physically impossible, but to not have some record of where the recombinant DNA use is or what their chemical use is. We can then use that information to effectively fingerprint*

> *the campus for the locations of the hazards are. The information can be useful for task-specific training and management of hazardous waste at Dartmouth. This sort of tracking is also useful for teaching how a chemical process works, which information that's consistent with the educational piece then is information that can then be translated and used in new context...*

The Dartmouth accident reemphasized the importance of doing hazard assessments and gathering all the information about the process and the chemicals to be used. It also emphasized the importance of using accurate chemical hazard information. Work on glove analyses and revision of the OSHA Safety Hazard Information Bulletin on Dimethylmercury helped to improve the information available (56). Blayney also discussed the lab-specific application of hazard assessment.

> *Permeability is an example of something that is defined by the material used, the nature of the chemical, and the nature of the exposure... Because that risk assessment can't be done by a safety function. That can't be separated. It needs to be part and parcel of the process the scientists engage in every day to do their own risk assessments and a lot of that's unconscious to people... Oh, it's really snowing out today, the roads are dangerous, I don't need to drive. They've conducted a risk assessment, you know, they've taken a step to minimize that. (48)*

Asked whether hazard assessments were done at Dartmouth , former Dartmouth science students answered that they were not aware of them being done.

Safety Committees

Safety committees have become a standard feature of workplace safety programs in many industries and sectors. However, committees themselves do not necessarily mean effective student or employee involvement. In some configurations, they are policy making bodies, in others they are there to facilitate safety laboratory practice (149). There are also, macro-scale safety committees that have members from all parts of the campus. There are micro-scale department level safety committees and school safety committees, combining several departments. In some institutions, the macro safety committees are made up only of faculty and EHS staff. For safety committees to function on a micro-scale and to help exchange information between laboratories, they should have student and laboratory staff members. These committees should have real power to implement change. Criteria for good safety committees are: department specific committees, regular meetings with content including discussions of accidents or near misses, and student involvement in them.

UCLA

From the UCLA website: A campus wide laboratory safety committee was formed in January, 2009. It provides general oversight and guidance to the campus through policy promotion of a safe work environment in all research and teaching laboratories. The Committee advises and reports to the UCLA Chancellor through the Executive Vice Chancellor. It consists of members of many departments and reflects the diversity of scientific disciplines involved with Laboratory Safety on campus. In addition to providing oversight and guidance, the LSC has the authority to modify, suspend, revoke and terminate any laboratory activities that are deemed to pose an unacceptable risk to life or safety (142).

The Laboratory Safety Committee and EH&S conducted a comprehensive review of campus laboratory safety, which resulted in a report to the UCLA Chancellor on

Laboratory Safety. The report evaluated the existing programs and resources in place at the time of the report. It also identified areas in programs and resources where improvements were needed and made recommendations for action to improve laboratory safety in all research and teaching laboratories across UCLA. The LSC did not have any representation of students and only one non EHS and non-faculty staff member was on it. There is one super committee and no other safety committees. Students do not report involvement in safety policies or decisions. (142)

Northwestern

On a macro scale there is a laboratory and chemical safety committee that is a policy setting body (42). "This group will independently review incident reports. They will formulate policy for the vice president for research. And this will be a group that will also participate in the high hazard reviews or process hazard reviews" (41).

According to a chemistry graduate student, safety officers from labs attend department level safety committee meetings. (150) "There's a monthly meeting that involves safety designates from each lab. It's for chemistry and materials science and it's a once a month meeting. That meeting is where discussion takes place about incidents or near misses". Also at these meetings, safety designates from the lab groups present a best practice and a process that is of interest to people in the committee (42).

Dartmouth

Michael Blayney reported, "At Dartmouth there are three critical committees: radiation, biological and chemical safety committees. They meet quarterly. Dartmouth also has a chemical safety advisory committee. EHS can communicate with key faculty members on those committees. How well those messages disseminate though is very complicated depending on institutional culture (48). EHS runs and administers the committees so communication is good between them." No students participate in on safety committees.

Recordkeeping

It is very important for EHS to keep track of basic procedures like inspections and training. In the case of the UCLA accident, UCLA had incomplete training records so they could not document that people had had any training (18). At the macro-scale, institutions should a system where they identify labs; register the projects associated with them and the personnel there to make sure that all those pieces are matched, either for providing institutional assurances for grants or just routine recordkeeping that passes through committees (48).

At the micro-scale, individual recordkeeping is also important. A logbook of all processes and procedures performed in the course of research which should be kept in such a manner as to enable an investigator to reproduce the steps taken. This should be taught to all laboratory personnel. This was an important finding in an investigation of the Texas Tech Accident that found that it was difficult to recreate the procedures that preceded the accident because of the quality of information in the lab notebook (3). Best practice for documentation is a system of documentation of training, inspections, instruction in keeping lab notebooks. No information was collected on micro-scale record-keeping for this investigation.

UCLA

According to James Gibson, recordkeeping and documentation of training by both EH&S and lab managers has become much more stringent since the accident. This is probably very true because Gibson has said that there were no records in 2007 of any training having taken place at all (18). Using LHAT, EHS is able to schedule and track training and inspections through increased/standardized reports.

The following information was obtained from UCLA the EHS Director on the state of information gathering through LHAT at this point (December 2011) (147).

- 772 of 1,065 Active PIs have completed the LHAT
- 615 of 1065 Active PIs have completed PI training
- A total of 5,554 people have verified PPE training through the LHAT

Cal OSHA cited UCLA for deficiencies in training and inspections and for a lack of record-keeping. It appears that the implementation of LHAT, would improve record-keeping.

Northwestern

ISIS is NU's on-line safety data management tool used by PIs to submit applications and registrations for review. ISIS also builds a lab-specific Laboratory Safety Profile for each researcher and serves as an educational resource for PIs and laboratory workers. The ISIS system, implemented by the ORS department enabled better tracking of training and inspections. It was in development for five years (41), before the NU accident occurred. It was in place during the accident.

Dartmouth

Michael Blayney has said that Dartmouth "has a system of record to identify labs, register the projects associated with them and then the personnel there to make sure that all those pieces are matched, either for providing institutional assurances for grants or just routine recordkeeping that passes through committees" (48). No other evidence was presented.

Training

Safety training is a vital component of the laboratory safety program within the academic institution. Health and safety training is an important part of managing workplace hazards and risks. This type of training may involve instruction on identifying risks and how to control them, learning about safe workplace practices and how to properly use personal protective equipment. The university should provide ongoing safety activities that serve to promote a culture of safety in the workplace that will begin when the person begins work and will continue for the length of their tenure (1). Continuous reinforcement of the importance of safety throughout the chemistry educational process is required to instill a strong positive attitude in safety.

Several laboratory safety specialists have written about the importance of safety training. Robert Hill (a scientist at the Batelle Research Institute and a recognized expert in the field of laboratory safety) in an article entitled "The Emergence of Laboratory Safety" has written: "While a single course in safety is one valid approach, it cannot be used for freshmen, sophomores, or perhaps even juniors since their understanding of chemistry will not be developed to an extent to understand principles and terms that may be covered" (151).

Michael Wright, the Safety Director for the United Steel Workers of America wrote, "Safety requires a number of simultaneous approaches. First, there has to be rigorous education -- not just a set of rules, but a broad understanding of the reasons for the rules. Realistic, repetitive training can go a long way to ameliorating panic reactions in emergency situations. Alas, the resources and institutional commitment for this sort of thing are lacking in most academic situations, and for some folks it just won't ever sink in" (113).

Peter Reinhardt, EHS director at Yale University says, "Making training more accessible is one of the best things an EHS department can do". Yale, like UCLA, has produced dozens of training videos over the past decade. "Training is prevention, so we spend a lot of resources on it." Best Practice for training includes frequent training (not just once as freshmen), specialized training for specific types of labs and of hazards, good recordkeeping of who has been trained and when the last training occurred. Indicator criteria for good training are periodicity, specificity, and recordkeeping.

UCLA

Oversight and training in laboratory safety has become far more rigorous — from the principal investigators down to the undergraduate students since the accident. In 2010, 11,392 lab personnel completed classroom lab-safety training and 6,631 completed online lab-safety training — a 25-fold increase over 2007 (34).

UCLA EHS offers training courses every week, with special sessions available based on demand. Many training resources are now online, including a lab-safety manual and a chemical hygiene plan, as well as the videos on handling pyrophoric chemicals, fire safety and other laboratory safety topics. Access to these is through the EHS web page (142). According to the Training Website, all laboratory personnel are required to attend a, lab-safety fundamentals class before they start working in the lab. In addition, principal investigators now receive in-depth training specific to their specialty (142). The training matrix is very extensive.

UCLA's online training matrix is extensive and outlines the minimum medical & training requirements for personnel working in research settings. The training is aimed at PIs, Lab Supervisors, research personnel, graduate students & undergraduate students in research laboratories as well as general staff working in laboratories and animal housing facilities. A matrix is provided to help people understand what training is required for the type of work they are doing and the type of lab they are working in (142). According to James Gibson, UCLA conducts "a mandatory training for PI's and Lab Supervisors, which has been well-received by the PIs" (147).

Northwestern

The pattern of training required at NU has not changed since the accident. As before, basic safety training occurs at orientation (41). "New laboratory workers get a list of trainings they need to complete and when they complete the training, that information is entered into ISIS and then ORS can see if somebody is fully trained or not" (39). A former engineering student at NU reported that they went over laboratory safety every quarter that they took a lab class and had to pass a safety quiz before they were allowed in the labs (152).

Only respiratory protection training is required yearly unless conditions change. Training is available in both classroom and online. Table 35 shows technical specificity and periodicity of lab safety training at NU.

Table 35 Lab Safety Training Table from NU Website

Type of Training	How to know if you need the training	Required ?	Repeat ?
Compressed Gas Cylinders and Cryogenic Liquid Use / Storage Training	Do you use or store compressed or liquefied gases?	Yes	Change of Condition
Laboratory Standard and PPE Training	Do you use or store hazardous chemicals inside a laboratory?	Yes	Change of Condition
Respiratory Protection Training	Do your job duties require use of an air-purifying or supplied-air respirator for protection from exposure to hazardous chemicals or dangerous atmospheres?	Yes	One year

Dartmouth

Michael Blayney had these comments on training at Dartmouth, "Training alone in the absence of a viable safety management function is not going to do any good because there's nothing there to help facilitate people. Training alone is not necessary, unless it has value or perceived value to the individual, and is going to be internalized where people are going to act on it, because we all have different perceptions of risk and different locus of control with that" (48).

Training specificity has changed with the diversification of subjects studied at Dartmouth. Michael Blayney had additional comments about training challenges, "there is up to 25% turnover each year in the cohorts that EHS needs to contact and provide training to. Current practice is training to the desired outcome. So training is task specific."

Michael Blayney added, "There are obligations under various regulatory schemes to train initially and then retrain. We train on very basic things that would constitute prudent practice, but if we don't train future scientists to think about those things, and then reinforce and instill those behaviors so that from the perspective of the people you serve, these are individual choices people have to make to wear safety glasses so we provide safety glasses during training" (48). A former Dartmouth biology student reported: "There would usually be training at the beginning of each course, and also at the beginning of each lab session in a course. For my jobs in labs, I was usually just trained personally by the post-doc I was working for. I think I might have gotten certified in lab safety with a one-or-two-lecture thing through Environmental Health and Safety" (150). Table 36 shows the Dartmouth laboratory training modules available on the EHS website.

Inspections

A program of periodic laboratory inspections helps keep laboratory facilities and equipment in a safe operating condition. Inspections safeguard the quality of the institution's laboratory safety program. (1) Information on the benefits of inspections and prescriptions for best practices are provided in the 2011 Prudent Practice guidance document (1). According to Prudent Practices, "Laboratory inspections should be performed by EHS staff, the Chemical Hygiene Officer (CHO), the safety director, laboratory staff, a safety committee, or an outside entity with the requisite qualifications and experience"(1). The inspection checklist can include sections on chemical storage, chemical waste, housekeeping, PPE, laboratory chemical hoods, gas cylinder storage, emergency safety equipment, signs and labels, and facility issues (1).

Table 36 Lab Training Modules Available on the Dartmouth EHS Website

Biomedical [Molecular Biology] Lab Safety	Mandatory for all personnel working in a biomedical/ molecular biology laboratory
General Laboratory Safety	Mandatory for all personnel working in a laboratory in the Arts and Sciences (Chemistry, Earth Sciences, Physics, Environmental Studies) and Thayer School of Engineering.
Management, Minimization and Disposal of Hazardous Chemicals	Provided via the EHS web site. This course is mandatory for all individuals working with chemicals in a laboratory. This training must be current within three years.
Radiation Safety-Basic	This training is for all individuals who will be working with radioactive materials or other sources of ionizing radiation.

Radiation Safety-Retraining	This is an annual training requirement for all personnel working with radioactivity.
Radiation Safety--X-Ray Users	For all individuals working with equipment that generates ionizing radiation.
Laser Safety Training	For all individuals working with Class II and above lasers. Biomedical [Molecular Biology] Lab Safety

Prudent Practices describes several types of inspections including program audits, EHS audits, and external audits (1). Audits should happen on a regular basis but also could be impromptu. Important considerations for an inspection program are checklists of important items to check and to monitor, established consequences for non-compliance. Criteria for evaluating inspections are frequency, specificity, and consequences.

UCLA

UCLA EHS began a major overhaul of its compliance inspections, which increased from 365 in 2007, (the year before the accident), to nearly 2,400 in 2010 (34). The inspection checklist was revised and now is eight pages and includes 60 new items, 23 of which require corrective action within 48 hours if a lab is found to be out of compliance (all other re-inspections occur within 30 days) (34). Reports are now issued to lab managers on the next business day so that any violations can be addressed immediately (18). In 2010, EHS began conducting surprise inspections for labs with many violations, as well as those that had left deficiencies uncorrected at the time of the first follow-up (34).

Northwestern

The following description of a basic inspection was found on the NU Website from 1995. Steve Karlman wrote: "The basic NU inspection is simple. After the PI responds to our request to schedule a survey, we visit the lab on a convenient date and time. First we interview the investigator or safety designate and ask about the work performed in the lab, the people working in the lab, and the types of materials and procedures used. We check paperwork such as the Safety Plan, Hazard Communication Program, and Safety Desk Book. Then we move into the lab and examine chemical storage, fire protection equipment, general housekeeping, personal protective equipment, engineering controls, access and egress, compressed gas cylinders, electrical safety, electrical appliances, and signage. Finally, we meet with the investigator or safety designate to go over the results of the inspection and make any suggestions for improving safety…" The NU formal lab review happens twice a year and the EHS staff tries to also visit at other times.ORS uses ISIS to track inspections. This has not changed since the accident.

Dartmouth

The primary elements of Dartmouth's Chemical Safety Program are presented on the EHS website and include periodic compliance inspections, written policies and procedures, training, emergency response and registration of high hazard work (153). Inspections are required as often as every six months or as infrequently as 18 months (48).

The following categories are on the Dartmouth inspection checklist(153).

- General Postings and Policies

- General Emergency/Safety Equipment
- Hazardous Chemical Storage and Safety Check
- Gas and Cryogen Safety
- Chemical Fume Hood Safety
- Hazardous Waste Collection and Storage
- Electrical Safety and Equipment Check
- General Safety and Housekeeping

Hazardous Waste Management and Disposal

The first steps in managing chemical wastes are selecting the least hazardous chemicals for the task and ordering chemicals only in quantities really needed. Chemicals should not be kept in laboratories if they will not be needed, especially if they are peroxide-forming chemicals, polynitro compounds, or chemicals that are air-or water-reactive. Waste minimization and pollution control techniques, such as recycling and the development of more efficient or nontoxic synthetic routes, have gained increasingly high priority as the cost of waste disposal has escalated.

Best practices in hazardous waste management include the following: 1. safe storage and handling procedures, 2. surplus sharing, 3. chemical inventory, and 4. waste minimization (154).

UCLA

Cal OSHA cited UCLA for insufficient management of hazardous chemicals. In 2010, after the accident, a hazardous waste policy was put in place for the safe storage, use, handling and disposal of particularly hazardous substances. The list of particularly hazardous substances includes more than 100 chemicals that have been identified by regulators as carcinogenic or reproductive toxins (34).

Prior to the accident, in 2007, UCLA EHS conducted a inventory exercise to search for Department of Homeland Security (DHS) Chemicals of Interest in response to the DHS Chemical Facility Anti-Terrorism Standards (CFATS) Final Rule (6 CFR Part 27) in the Federal Register. DHS COI is a list of toxic and hazardous chemicals compiled by the DHS (155). This regulation requires any facility that possesses amounts of the COI above certain quantities and concentrations to provide a detailed inventory to DHS. In order to comply with CFATS, EHS conducted a campus wide survey of laboratories, stockrooms, and other areas where chemicals are used or stored. The deadline for submitting the survey to EHS was January 1, 2008 (155). This process was ongoing when the accident occurred in December 2007.

However, the procedures and resources for handling hazardous chemicals have been improved since the accident. A video was posted on the UCLA EHS website in October 2009 on hazardous waste management. This is the same date that a video about pyrophoric chemicals was posted on the website (142). The UCLA website also provides Information on waste minimization. The website states that UCLA EHS believes in the minimization of all wastes so they have developed the Hazardous Waste Minimization Program on campus. The objective of these programs is to minimize the costs, health hazards, and environmental impacts associated with the disposal of hazardous waste. EHS also has a surplus sharing program (142).

Northwestern

NU's hazardous waste program has been in place for several years. ORS has used Chemtracker to inventory laboratory chemicals as well (41). On NU's website, there is information about waste minimization. Table 37 presents information on hazardous waste management from the NU website.

Table 37 Information on Hazardous Waste Management from the NU Website

Waste Management Information necessary for managing chemical waste inside your lab.	Waste Disposal Disposing of chemical waste and other specialty chemicals.	Waste Minimization Alternative means of hazardous waste management designed to reduce the amount of chemical waste a lab generates.
Labeling waste	Waste removal by ORS	Waste minimization
Storage of wastes	Disposal of pump oil	Sanitary sewer or ordinary refuse disposal
Containers for waste collection	Disposal of unknown chemicals	Acid Neutralization and Base Neutralization
Collection of sharps	Disposal of reactive and unstable materials	
Mixed waste issues		

Dartmouth

Dartmouth College has had a comprehensive Hazardous Waste Management, Waste Minimization and Disposal Program in place for several years. This is spelled out in the flipcharts given to all the labs. The chemical waste program includes definitions of hazardous waste, labeling, procedures for disposal and instructions for different types of waste. The improper disposal of hazardous materials is strictly forbidden. Detailed information and assistance on hazardous waste disposal is provided by EHS on the Dartmouth website and flipcharts (153). Information about hazardous waste policies are on a restricted portion of the EHS website. The flipcharts available to all laboratories have a great deal of information about types of hazardous wastes and how to handle them.

Emergency Planning and Response

The College Opportunity and Affordability Act (COAA)(H.R. 4137-2008) mandates campus safety and disaster readiness plans development. Most universities are prepared in some fashion for chemical spills and minor exposures. However, a myriad of unexpected events may happen. This could range from floods and hurricanes to terrorist attacks. The responsibility for and level of detail of the plan will vary depending on the structure of the institution and institutional planning efforts already in place (1). The information on emergency planning for each case was obtained from the University website. Each of the cases has a version of this safety climate component and the extent to which they are prepared is instructive. Every institution, department, and individual laboratory should have an emergency preparedness plan as a basic policy.

UCLA

The UCLA Campus Departmental Emergency Response Plan Template is located on the EHS website. The template has instructions for most of the emergencies that are listed on the EHS website plus accommodating people with disabilities and emergency contacts. UCLA's items are listed right on the website.[16] The UCLA Emergency Management Office is a separate entity from the EHS Department but it is overseen by James Gibson, the EHS Director. This policy has not changed since the accident.

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[16]http://map.ais.ucla.edu/portal/site/UCLA/menuitem.2bceb61fc98129c1ae13e110f848344a/?vgnextoid=cba9a75eb8724110VgnVCM100000dcd76180RCRD.

Northwestern

NU has a decentralized approach to Emergency Management. As with Safety in general at NU, responsibility for Emergency Management is also divided into three departments. The emergency information is divided up between the ORS and the office of risk management which lists insurance-related issues. Institutional emergency preparedness is coordinated by NU Police and the Threat Assessment Group (TAG)(39). The NU Employee Safety Handbook covers emergency procedures. It also covers security, blood borne pathogens, chemical safety, laboratory security, and hazard communication. The information on a small subset of possible emergencies is available on the NU ORS website. NU list of emergency topics covered appears on the NU emergency website:[17] and an Employee Emergency Handbook which is accessible through links on the website.

A separate department to handle emergencies at NU has been in place since 2008 when Clement Stokes was hired as Director for Emergency Management(156). He is the only employee in that department at this time. Mr. Stokes reported that a new emergency response website was coming out soon. A police website was found [18] The website contains a list of "vulnerabilities" and an emergency response framework.

Dartmouth

The Dartmouth website has information on fire safety on its website and on the lab safety flipcharts handed out to each lab. There is a fire safety poster specifically aimed at students. EHS is involved with Emergency Response. The Dartmouth College

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[17] http://www.northwestern.edu/emergency/general-procedures.html
[18] http://www.northwestern.edu/up/emergency/index.html.

Emergency Response Guide is downloadable from the EHS website. It has information on a great many circumstances where help might be needed. The Dartmouth College Emergency Response Guide has the list in the table below covered. A subset of this list is on the website. The Guide is available through a link on the website.[19] Table 38 shows the emergency topics available on the university websites or in their safety handbooks. This list of topics covered by NU's Emergency Plan is much smaller than the other two institutions.

Table 38 Comparison of Emergency Topics Covered by the Emergency Plan Webpage

UCLA Emergency Topics covered on the EHS website	NU Emergency Topics covered on the University website	Dartmouth Emergency Topics covered on the EHS website
Fire & Conflagration		Fire
Active Shooter		Fire Prevention
Evacuations		Building Evacuation
Accommodating People with Disabilities		Special assistance and disability evacuation plan
Explosion		Medical Emergencies
High Rise Fire Alarm System		CPR Procedures
Terrorism		CPR for a baby
Civil Disorder		Choking
		Seizures
Storm & Flooding		Floods
Earthquake	Earthquake	Earthquake
	Tornadoes thunderstorms	Tornadoes
Power Outage	Power outage	Power outages
Bomb Threat	Bomb threat	Bomb Threats
Suspicious Package	Suspicious activity	Suspicious packages
Shelter-in-Place	Violent behavior	Threatening or violent behavior
Chemical Spills	Chemical spill	Communicating in a crisis

[19] http://www.dartmouth.edu/~ehs/docs/emergency_response_guide.pdf.

Table 39 presents a qualitative summary of how each cased fared in the safety climate procedure assessment.

Table 39 Safety Climate Procedure Assessment			
Procedures	**UCLA**	**Northwestern**	**Dartmouth**
External Communication : Available to public. Available to EHS community.	UCLA's efforts to communicate about the accident and the challenges in improving laboratory safety are laudable but they may be a smokescreen for a cultural deficit. As stated earlier, these actions put UCLA at the forefront of the campaign for improvement, at least of the procedural elements in the model.	Northwestern, in its own right, has not been as splashy but has quietly discussed the accident for the benefit of the chemistry and chemical health and safety community and produced an award winning EHS newsletter.	Dartmouth, in response to Karen Wetterhahn's accident, publicized the hazards of dimethylmercury and caused a reexamination of the use and handling of it. This was done through scholarly articles and scholarly research. Information about the accident changed and OSHA regulatory policy document, public opinion, EHS practice outside of the university.
Internal Communication : Available to students and staff at the university	UCLA has made some efforts at improving communication between EHS and the science departments. A great deal of information has been made available to them as to training requirements, inspection requirements and the efforts being made to reign in and document	NU has improved internal communication by hiring a safety specialist specifically to work with the chemistry department. ORS staff have discussed creating a wiki site for documentation of students' procedural questions. This would be an avenue of	Dartmouth provides internal information through extensive hanging safety binders and an informative website. However, there is no indication of upwards communication.

	safety practices. These include training videos that are available externally as well. However, this is only downward and outward communication. There is no indication that communication from the students as to near misses, or safety concerns are entertained or addressed in any fashion.	upwards communication.	
Incident Reporting	Some of UCLA's procedures have changed but whether the incentives and atmosphere for reporting have is uncertain. Procedures and requirements have been established for reporting.	Students at NU are reported (by ORS and a graduate student) to be comfortable reporting incidents. At least that is the goal.	Dartmouth explicitly promotes a non-judgmental approach towards reporting near misses or spills. Dartmouth students are actively encouraged to report incidents.
Hazard/Risk Assessment	UCLA developed the LHAT to assess overall risks in laboratories on a macro-scale and to find out the type of training needed by personnel in the lab. However, specific pre-procedure risk assessment activities were not documented.	NU practices both macro (using ISIS) and has begun to perform pre-hazard analyses on a micro-scale with the help of the safety officers and the safety committees.	Dartmouth tracks macro-scale hazards but former Dartmouth students reported no memories of risk assessments explicitly being done but pre-experiment safety instruction did occur.

Safety Committees	After UCLA's accident, a university wide safety committee was convened to assess health and safety practices and deficiencies at the University and suggest ways to improve them. The committee was made up of administration officials and EHS staff. No students were involved.	At NU macro level safety committees make policies and review incident reports. Micro-scale safety committees are formed with safety designates from different labs.	Dartmouth has three critical committees: radiation, biological and chemical safety committees. There is no student involvement in these committees.
Recordkeeping	UCLA's recordkeeping procedures have improved since they were cited by Cal OSHA for not documenting training. They have Increased and standardized inspection reports.	NU's ISIS system is an excellent tool for tracking inspections, training and chemical safety that has been in place since before the accident.	Dartmouth has a system which tracks laboratories and projects. It has formed since the accident.
Training	Training at UCLA has improved greatly since the accident. UCLA's training has increased in frequency, specificity and recordkeeping has improved. There is now training for PIs, for using pyrophorics, lasers, etc. Training needs are identified by	Training periodicity has remained the same and specificity has changed with the changing needs of the labs. None of this has changed since the accident. At NU, ISIS is used to schedule and track training. Students have said that safety	At Dartmouth, students are trained initially and retrained as needed. Training is available and done for specific identified hazards. This protocol has definitely changed since the accident (which occurred in 1997).

	LHAT.	instruction took place at the beginning of every laboratory class. Training takes place yearly unless conditions change. Specialized training is done for different types of labs.	
Inspection	UCLA's inspections have increased in frequency, in quality and in effectiveness. Sixty items were added to the inspection checklist. The policy includes impromptu inspections with the vice chancellor.	At NU, ISIS is used to keep track of inspections needed and performed. Inspections are performed at least twice a year.	At Dartmouth, training is prescribed by the nature of the work being undertaken by the lab. It is required as often as every six months or as infrequently as 18 months.(48)
Hazardous Waste Disposal	Since the accident, UCLA has extensive instructions about waste handling and management on their website. Waste minimization and surplus sharing programs may have been in place prior to the accident. The CFATS inventory was underway when the accident occurred.	NU has extensive instructions about waste handling and management including information about inventory and waste minimization available on their website. These programs have been in place for several years.	Dartmouth has extensive instructions and comprehensive waste handling and management programs in place.
Emergency Planning and Response	UCLA has the Comprehensive	At Northwestern, emergency	Dartmouth's emergency response guide is extremely

	Emergency Response Guide available and accessible on the EHS emergency management website. They have done planning for contingencies and many are listed on their website. Emergency planning is under the direction of the EHS Director.	response is decentralized. It is not covered by ORS. It is covered by the NU Police and the Threat Assessment Group (TAG), totally separate entities from ORS department. The emergency topic list on the NU website is not comprehensive and not easily accessible.	comprehensive and is available and accessible on the EHS website.

Safety Culture Values Assessment

The assessments that follow relate to the values in the Safety Culture Model. For each value, an explanation of the background and importance of it as well as criteria for evaluation of the cases' performance are presented. The characteristics of the value and how it was addressed are presented for each case. This assessment begins by examining the core value of the safety culture model, Management and Employee Commitment to Safety. It is this value from which all the safety culture values emanate.

Management Commitment to Safety

Most models and discussions of safety culture located in the literature include management commitment to safety as a critical, if not the most critical value. Management commitment to safety is the foundation for safety culture. Management commitment to safety promotes trust and accountability. Unclear management support leaves EHS with weak authority. Management commitment to safety provides support for EHS, Chemistry Departments, and PI safety efforts and encourages student and laboratory staff participation in safety programs. Defining who has ultimate responsibility and supporting that policy establishes lab safety as an essential priority and effectively communicates safety priorities and goals.

Several components must be in place for effective management commitment to safety in an academic environment. In this evaluation three subcategories are considered components of management commitment and were included as subcategories of management commitment to safety. They are: 1. Resources, 2. Administration support, and 3. Administrative reporting structure. PI accountability and discipline are also related to management commitment but are discussed separately. The three components are defined below. The discussion following the description provides data from each institution for each subcategory component.

Resources

Indicators of good support from management for safety activities are adequate resources in the form of staff or facilities and funding for programs and staff, policies, and administrative assistance. Of interest is whether and how safety resources have changed since the accidents.

UCLA

The State of California and the University of California (UC) System in general are short on money (157-160). Therefore, the UCLA EHS Department is likely underfunded. James Gibson, Director of EHS at UCLA has said, "research in areas such as nanotechnology and biochemistry has grown exponentially but the resources have not increased commensurately" (18). This is not unusual in academic institutions, especially state run institutions. However, UCLA has gained some visible support. At the time of this writing, two EHS positions are being advertised on the UCLA employment website. In addition, UCLA and the UC system has created the University of California Center for Laboratory Safety to support research in laboratory safety and facilitate the translation of results into best practices on the campus, as well as at other universities and research organizations (36). Although UCLA has created the Center for Lab Safety, it has no physical presence at this time and only has one staff person – a PhD student who receives funding from the center. The budget is less than $200,000 per year (161). The Center is seeking grants to perpetuate it. Thus, the value and impact of this center has yet to be proven.

As of May 2011, the UCLA EHS organization chart lists a total of 68 staff. There are 14 staff working on radioactive materials and lasers, 13 working on biosafety (with one vacancy), 8 on fire safety, 11 work on environmental issues (with one vacancy), 10 work on ergonomics and injury prevention, 6 work on training and outreach (one vacancy), 2 emergency preparedness, one program analyst, and one director (142).

Northwestern

In a move that was afoot prior to the accident, although accelerated because of it, NU hired a safety specialist specifically to work with the NU chemistry department. Nick Waddell was hired to be a safety resource dedicated to the chemistry department. He has a chemical engineering background which gives him credibility with the chemistry students and staff (42). He has worked hard to gain the trust of researchers and PIs and has helped students perform hazard assessments for the projects (42). The expedition of this resource came about directly because of the accident. No other changes were made to increase staffing.

Dartmouth

Dartmouth EHS employs a small staff. There are nine EHS employees and three FT equivalents that deal with laboratory-related safety (48). Compared to other institutions, Dartmouth has a much smaller department. The number of staff increased soon after the accident (a chemical hygiene officer was hired) (53).

Administration Support

Support of the administration is indicated through safety oversight from levels above department chair. This value indicates support from above. Examples of support from university administration include attention to and care about safety issues, supply of materials or support for programs and initiatives.

UCLA

Before UCLA's accident, laboratory safety was out of focus for the UCLA EHS Department and the Chancellor. James Gibson, relatively new to the director position, was addressing issues that needed immediate attention outside of laboratory safety. EHS now has received a great deal of attention from administration through the accident and Cal OSHA findings (20) and the Los Angeles District Attorney's felony charges(32). Since the accident the chancellor has directly participated in inspections (34).

Northwestern

The NU Administration supported the development of ISIS which enabled automation of inspection and training records (41). This support occurred before and after the accident.

Dartmouth

Administration support for safety programs at Dartmouth are ongoing and have been in place since the accident. The EHS director reports to a Vice President and the EHS department has channels through to the Provost (48).

Organizational Structure of Safety and Science Departments

A reporting structure that connects safety culture to academic life and to management authority fills in gaps in administrative support. It is important to ensure that the reporting structure allows for communication of safety information to those within the organizational hierarchy that have the authority and resources to implement safety change

(3). The position of EHS in the organizational structure of the administration is important for EHS to have authority and oversight over safety in the laboratories. This organizational structure was recognized by the CSB as a component contributing to the accident at Texas Tech. (3)

For the purposes of this assessment, the following elements constitute good organizational structure: 1. EH&S has the authority to shut down a laboratory and the EHS department is positioned within the university to enable this authority. 2. Ideally, all EHS functions, including hazardous waste and emergency management are under one director and have support of a dean or provost.

UCLA

EH&S realigned its organizational structure and formed the Research Safety Division (RSD) subsequent to the accident (162). UCLA EHS reports directly to the Administrative Vice Chancellor. The date on the organization chart with this configuration is October 13, 2011. Since the accident, EHS has set up new guidelines on the Lab Safety inspection process, which connects safety in academic labs directly to administration. This connection is shown in a flow chart that is available on the EHS website[20]. UCLA reports that they shut down one laboratory since the accident (147). This process was revised on February 7, 2011.

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[20] *http://ehs.ucla.edu/Pub/RES_Lab_Safety_Inspection_Flowchart.pdf*

Northwestern

As described earlier, NU has a decentralized approach to safety (38). The NU ORS handles research safety. According to Todd Leasia, their jurisdiction also includes blood borne pathogens and the hazard communication program throughout the university (41). ORS employs 24 people. There is a second safety department in the Office of Risk Management. That office handles general occupational safety, fire safety, workers compensation, the insurance function. This office is separate from ORS. Six people in that office have a safety function. A third safety component is facilities management and they handle compliance with respect to environment issues such as underground storage tanks, spill control counter measures, and waste water. A separate department handles emergency planning. Institutional emergency preparedness is coordinated by NU Police and the Threat Assessment Group (TAG)(39). This structure was in place prior to the accident and has not been changed subsequently.

Dartmouth

The EHS department is divided between the provost's office and the facilities department. The EHS director reports to a vice president and has channels through the provost largely driven by the circumstances. Financially, support is in facilities, but depending on the nature of the issue to be addressed, issues may pass through the provost's office (48). This structure has been in place for many years.

Accountability

PI accountability means defining the PI as the party who has ultimate responsibility and supporting that policy. The following ideas represent how accountability and oversight can be improved. Formal standards of behavior and performance are established for PIs in terms of lab safety. Resources are provided for PIs to meet the standards – e.g., training, inspections, advice from EH&S, safety committees. Appropriate consequences, both positive and negative, are established for performance. Policies are applied consistently throughout the Department and the University (163). PI responsibility and penalties are also elements of management commitment to safety.

The commitment to set these improvements up has to come from a provost or vice president of a university. Resources could include safety committee meetings where incidents near misses are discussed. Information resources such as toolbox talks, inspection results, hazard assessments could be made available.
In this evaluation two components were included under accountability. They are 1. PI accountability, and 2. Sanctions and penalties.

PI Responsibility /Oversight

A positive rating under PI responsibility would be that the PI has ultimate responsibility for safety in the laboratory. Formal standards of behavior and performance for PIs have been established in terms of lab safety. Resources are available to help PIs meet standards.

UCLA

There is no evidence that changes have taken place to "incentivize" increased accountability or oversight by PIs or Department chairs. However, the acknowledgement of its importance is there. James Gibson wrote: "the PIs take the safety of their staff and students quite seriously. As you probably know, we also conduct a mandatory training for PI's and Lab Supervisors, which has been well-received by the PIs" (147). Jane P. Chang, associate dean for research and physical resources at the UCLA School of Engineering and Applied Science, says "Everyone agrees safety is important, but if you're not thinking about it you can take it for granted, and that's when preventable incidents are more likely to occur" (34). The flow chart indicates that in the case of serious deficiencies that are not corrected, the inspection and report goes to the P.I., RSD Manager, EHS Director, Dept. Chair, Dean, Associate Dean, the Vice Chancellor of Research and Associate Vice Chancellor of Research. The flow chart further indicates that the process is repeated until the problem is corrected. There is no indication of consequences for the PI if this happens (142).

The policy at UCLA is that the PI is accountable for safety in the laboratory. This was acknowledged by the Chair of the Chemistry Department (164), who said "there are many sticks and they are 'incentivized' to be responsible". However, it is not clear that in actual practice this is the case. In a presentation given by James Gibson at the American Chemical Society meeting, responses to questions from the attending audience did not resolve the issue (165). Of course in UCLA's case, accountability may be decided by the

Los Angeles District Attorney who, on December 28, 2011 brought legal action against Patrick Harran, the PI of the lab in which the victim worked (166) and UCLA (25).

UCLA has started to do specific PI training. "PI training is really helpful in informing faculty about regulatory requirements and their responsibilities," says Hilary Godwin, a professor in the School of Public Health and vice chair of the UC Center for Laboratory Safety's advisory board. "But it's also critical as a way of changing the culture, because if we want the importance of safety to be reinforced throughout the labs, the PIs have to be on board." (34). Rita Kern, a member of the health and safety committee of University Public and Technical Employees (part of the Communications Workers of America) UPTE-CWA Local 9119 reported that "Accountability has been made clearer" (33). The oversight by the EHS department has improved. Inspections are more frequent, more comprehensive. Penalties for deficiencies have been defined and follow up has taken place UCLA went from basically zero documented trainings to 4,000 that first year, roughly 6,000 the year after that, to over 11,000 this last year, documented training (18). Recent information is that of 1,065 Active PIs and 772 of them have completed the LHAT and 615 of them have completed PI training (147).

Northwestern

The powerful and important example of a PI taking responsibility for the students in his lab was described in the case description earlier in this document (44). This process was presented to a meeting of the NU chemistry faculty. However, it is not known how wide spread these practices are and how they were received by the faculty. The PI gave credit for some of his innovative actions after the accident to other colleagues (44).

Todd Leasia reported that "PI accountability is spelled out in University policy. Accountability statements abound – that state clear responsibility. Faculty can never release responsibility" (41). However, a department's culture often influences what is acceptable practice, despite written policies.

Dartmouth

Accountability is through the safety committees. Mechanisms exist for individuals who are less compliant. This was not elaborated on. These policies have developed over time since the accident (48).

Sanctions/Penalties

Compliance efforts need carrots and sticks. Strong sanctions and penalties are clear consequences for non-compliance. EHS needs the authority to enforce them. One example of a penalty at a university is that researchers are suspended from lab for 30 days if found without PPE. If it happens three times, the researcher is asked to leave (167). Another example is a progressive discipline program which goes from verbal warning, progresses to a written warning. Then to a leave of absence and finally to termination (168).

UCLA

Before UCLA's accident, inspections and training were not comprehensive, well carried out or well documented. These deficiencies were cited by Cal OSHA (20, 168). After UCLA's accident, structure was added to the inspection plan – including 60 new inspection items, and a time frame was set up to make corrections based on the severity of the problem. Labs have 48 hours to correct severe violations, 60 days for less serious ones (18). However, it is unclear whether the consequences for non-compliance have changed. According to the flow chart the inspection process is repeated until the problem is corrected. There is no indication of consequences for the PI if it not corrected, regardless of what the chair of the CBD says about renewed incentive for compliance and responsibility (164).

UCLA Policy 811 gives authority to shut down labs. On paper a lab can be temporarily shut down for a serious violation. Here is how Dr. Gibson described the process in a presentation at the American Chemical Society Meeting "if it's something egregious,… I have the authority ... if it's critical, it's not corrected, eventually if it's not corrected a couple times, then eventually it will make its way to the dean, to the department chair, to the dean, and to the Vice Chancellor for Research, and then we all confer and determine whether or not that procedure or that laboratory, frankly, needs to be shut down until they can get their act together and mitigate and correct those problems that are seriously not being done" (18). The Director of EHS says that this policy was used to shut one laboratory down (147). Details were not provided about this incident.

Northwestern

Sanctions and penalties were in place before the accident. According to Todd Leasia, this included severe penalties result if there is significant compliance breach. "There is a 'Death Penalty' at Northwestern, meaning that non-compliant labs get shut down." (41).

Dartmouth

In response to an inquiry about accountability, Michael Blayney stated, "If an issue was to ever rise to a serious level, the EHS Director has authority to shut down an unsafe activity. Non compliant labs are subject to sanctions by the Deans, up to closing the lab. Mechanisms exist for individuals who are less compliant" (48).

Collaboration

A collegial and cooperative environment may be rare in academic departments where competition between PIs for real estate and grants are the norm. However, collaboration between EHS, faculty, students is an important component of safety culture. A collaborative environment is conducive to safe practices.

UCLA

There has been increased collaboration between the chancellor and EHS to promote and improve the safety program since the accident. The chancellor and vice chancellor have accompanied EHS staff on impromptu inspections (18). The administration has sponsored additional staff and a center for lab safety. Collaboration between EHS and faculty took place in the university safety committee established after the accident to review safety practice and make recommendations for improvements to practice (18). There is no indication of differences in the level of collaboration between faculty before or after the accident.

Northwestern

The PI of the laboratory where the NU accident took place gave credit to colleagues for the ideas on how to comfort his students after the accident (44). In addition, he told about collaborations between researchers at Northwestern and at Argonne National Laboratory (44). According to the ORS staff, there is collaboration among the ORS Department and some collaboration among researchers. There is also collaboration between laboratories and ORS (42).

ORS works hard to collaborate with the researchers. Todd Leasia explained, "And one of the hardest things is then to get down into the trenches and develop an effective framework and the tools that can provide close collaboration with the researchers... So we do benchmarking and we watch what UCLA and others are doing but we're coming up with what for us are novel ideas to improve that collaboration environment" (41).

Dartmouth

According to Michael Blayney, EHS makes a point of developing collaborative relationships with faculty(48). "Since my arrival, this has been a key priority on an individual and collective level. We like to develop individual relationships with PIs (especially when first arrived) and with the Department Chairs" (169).

Transparency

Transparency is a method of conducting operations in such a way that it is easy for others to see what actions are performed. The right to be informed and to have access to the information has been an important issue for modern societies. As used in science or social context it, implies openness, communication, and accountability. Transparency policies were discussed at length in Fung et al. (170). According to Fung et al. "targeted transparency aims to reduce specific risks or performance problems through selective disclosure by organizations."

Transparency as a value represents openness and honesty in communication. Transparent communication is a dimension that received wide coverage in many of safety culture studies reviewed. Transparent communication is viewed as open channels between all levels, including between peers, communication of expectations and goals (72). Cox et al. (171) suggested that there is a reciprocal relation between transparent communication and trust, where open and honest communication is a sound basis for the development of trust, and where a high level of trust would further promote open and honest communication.

In line with the research the criteria for transparent communication in a university setting include honesty, reliability, compatibility, and accessibility. The criteria pertain to the ability of the information to be trusted, useful and ability to be acted upon. This is particularly critical in laboratory situations where people are working with hazardous chemicals. One way a safety culture pays off, as the levels of trust improve, is in the quality of communication between management, and the rest of the organization. As this is always pointed to as a source of problems, having a definitive focus for improving communication can only result in improved performance at all levels (108).

UCLA

External Communication

Since the accident, UCLA has worked hard in several arenas to provide information to the public and to the university community. This includes attempts to provide a defensive social media campaign that included James Gibson giving lectures and presentations to various groups such as ACS and CSHEMA and videos available on YouTube. The UCLA Newsroom Website reports the following:

"EH&S director James Gibson has made presentations at the request of the National Academy of Sciences, the Howard Hughes Medical Institute, the College Safety Health and Environmental Management Association, and other regulatory and academic bodies and professional associations. Most recently, Gibson gave a talk at the American Chemical Society's national meeting and exposition in Anaheim, Calif., on March 29, 2011" (which is available on YouTube) (36).

Resources such as safety videos have been made accessible to the UCLA community, the public and to other academic institutions.

Articles in the UCLA newspapers have been published about the efforts being undertaken by the university to address deficiencies in the safety program (34), (36). All of these articles strive to shine the best light on UCLA's efforts. These efforts are intended to provide evidence that UCLA is taking some action to improve a dangerous situation. Dr. Gibson even admits shortcomings in his talks. However, he talks about safety culture but shows that they are actually aiming at improvement in safety climate procedures, the low-hanging fruit – PPE policy, increased and improved inspections, improved training.

Inside the university many improved resources have become available to researchers on the EHS website since the accident. The information is easily accessible and compatible to the needs of students, and PIs. Some of these resources include EHS prepared facts sheets and safety videos on subjects such as pipette safety and ergonomics, fire safety, and hazardous waste management. On the UCLA CBD website there is a safety page where there is an SOP library for common chemicals and chemical groups and how to order a lab coat. The CBD website also provides PPE policies, a lab safety manual and principal investigator responsibilities (10). These are all areas related to safety climate procedures.

Internal Communication

There are many examples of internal communication regarding the accident and actions UCLA is taking to address the deficiencies found by Cal OSHA. Most have a definite Public Relations Spin to them. These include the findings and recommendations of the Campus Safety Committee called after the accident (162),Dr. Gibson's presentation to

ACS on YouTube, the announcement of the Center for Laboratory Safety is available on YouTube, and articles in the UCLA Magazine (34) and from the UCLA Newsroom (36).

Also indicative of the effort to improve transparency at UCLA is an email sent by UCLA Chancellor Gene Block to the UCLA student community on January 6 regarding the actions taken by UCLA in response to the death of Shari Sangji.

Sheri Sangji's death was strongly felt by everyone at UCLA, and we were deeply saddened by the loss of a member of our community. It certainly was the most devastating day in my tenure as chancellor. I made a pledge then that we would go above and beyond existing policies and regulations to become a model of campus safety. And we have. In the wake of this tragedy, we have enhanced our lab safety program in numerous ways to do all we can to prevent this from happening again.

> *First and foremost, we created the Center for Laboratory Safety, which has received attention from research institutions around the country. Its mission is to identify and institute best practices in safety, going beyond the minimum requirements of outside agencies so that we can hold our laboratories to even higher standards. We also dramatically increased the number of lab inspections, strengthened our policy on the required use of personal protective equipment and developed a hazard-assessment tool that labs must update annually or whenever conditions change.*
>
> *We know that improving lab safety requires a cultural shift and does not occur overnight. The process takes time and constant reminders — like the videos and social media campaign we've used to spread the message across our campus. One key component is emphasizing how lab safety is everyone's responsibility. Even when labs provide the tools, training, education and equipment, it's ultimately up to the individuals conducting an experiment to put their training to use and stay safe. We also*

> *emphasize each person's responsibility to speak up when they see individuals putting themselves in harm's way.*

This example and all public information released by UCLA about the accident is a mixture of acknowledging the accident without accepting responsibility and making it a call for advancing the field of campus safety.

Northwestern

According to the NU Director of Emergency Management, NU administration does not have a transparency policy and does not release details of accidents or emergency information. Detailed information about the accident such as the identity of the victim and injuries suffered by him were not released (38). However, the NU website is very accessible and provides valuable information for laboratory students and staff. It has compatible information for principal investigators, lab managers, lab workers, and workers outside of the labs. It includes links for General Lab Safety, Radiation safety, biological safety, rDna safety, laser safety, hazardous materials handling, hazard materials shipping. There is a safety inspection checklist for lab managers and PIs and instructions for reporting an incident. This website makes safety information transparent to the users. The information is accessible (on the ORS website) to anyone who needs it.

The NU ORS newsletter is a good means to provide information to the university community and to the outside world. It is publically available on its website and as stated earlier, the NU safety newsletters won an award from College Safety Health and Environmental Management Association (CSHEMA) for the best newsletter.

Dartmouth

Information exchange at Dartmouth takes several forms, typical of a small institution: personal communication, audio-visual, and a website. Michael Blayney is very opinionated about transparency, training and communication. He explained his direct approach to hazard communication within the university as influenced by the accident:

> *...we make a special emphasis to talk about particularly hazardous substances, and we define those as substances with a lethal dose 50 value, less than 50 milligrams per kilogram, which is the international convention of breakpoint between moderately hazardous or moderately toxic and highly toxic. And then we also add in the caveat that if it says anything about skin, you should take that to mean to avoid all dermal exposure because as we know with the difficulties of skin modeling that it could be a minor effect, it could be a major effect, it could be poorly defined or unknown. And so the upshot is that when you look at warning design or warning statements, I think we have opportunities to be a lot more explicit. So, for example, in the case of dimethylmercury, these are the gloves based on empirical testing that you need to wear because others are not adequate and avoid all dermal contact, or contact with this chemical in any form could be deadly just to be explicit about that. And that's not an institutional need, that continues today and remains a significant concern for all forms of warning information (48).*

Michael Blayney also reported having begun to produce media and that EHS has produced videos on how to deal with very active chemicals and machinery at Dartmouth(48). He expressed that one of his great interests is in hazard communication for international audiences and that videos could be a good vehicle for facilitating multi-lingual hazard communication. Videos of this type are being produced at Dartmouth. ...some of the media created... are indexed. ...The most recent piece is on an autoclave, how it works, ...showing the different pieces of parts of autoclave, but if you hear it spoken in English if you speak, Spanish is your native language, you'd want to see that tag in Spanish so that you can make a mental association when even if the English is coming a little bit too fast or faster than you might like, and I think that helps it, especially with science because science, independent of where we come from, also preps through safety practitioners. So there's these common techniques that are oftentimes used, and that's independent of language or background or experience (48).

The information on the Dartmouth website is accessible, reliable and compatible with the needs of the staff and student population. The following is information from the Dartmouth EHS website Chemical Safety Page. Among other things, it contains links to MSDSs, chemical storage compatibility charts, the lab inspection checklist, information on glove selection and references on dimethylmercury and the death of Karen Wetterhahn. It is unlikely that these last two items would be included on anyone else's website, a benefit that is a legacy of the accident. Another page continues information on training modules and training videos available. The website has a link to a method for checking what training had been done by students and staff. The only major component missing from the comprehensive website is links to alternative sources of chemical safety information.

Trust

An indication of a trustworthy environment is students and staff feeling comfortable going to someone with uncertainty or to report an accident or near miss in the laboratory without fear of reprisal. Policies in the university that encourage people working in laboratory environments to step forward to identify potential problems, report significant infractions in safety policies, or let responsible parties know of accidents are all indicators of an academic safety culture fostering trust. Reporting incidents is a similar issue to whistle blowing. Whistleblower's rights are protected by OSHA under 21 federal laws. These laws protect whistleblowers who report violations of workplace safety in many types of work places (172) .

UCLA

Graduate student mentors within laboratories help newer students to feel comfortable with the procedures and the hazards in the laboratory. Although there is no formal program, during a site visit, a graduate student was observed going to his "mentor" in a biology laboratory. When asked where he goes with questions about chemicals, he answered "to my mentor". His mentor turned out to be a fellow graduate student who had been there longer.

An undergraduate student reported: "I have never really felt unsafe in a chemistry lab at UCLA."

Northwestern

At NU ORS advocates the mentor model to help researchers find safe methods of doing research. In this vein, a safety officer was hired to be a resource specifically to chemistry department to answer questions about chemical risk and safety. He provides a level of trust that was not there previously. Todd Leasia remarked, "I think what we've provided in the person of Nick in a way is a mentor. That's a channel that didn't previously exist because of these other tensions in the laboratory" (41).

The actions of Joseph Hupp after the accident worked to regain the trust of the shocked students in the lab who had witnessed the accident (44).

From Students in response to the question: *Did you feel safe working with chemicals in the lab?*

One student commented, "Yes. There are safety procedures laid out, and the T.A. or whoever is running the lab is assumed to be knowledgeable and responsible." And another similarly commented, "I definitely always felt safe working with chemicals in the labs."

Dartmouth

At Dartmouth, EHS establishes a relationship with students at orientation and encourages inquiries. EHS provides general information on flip chart given to each student. According to Michael Blayney, EHS holds a big orientation event for freshmen where he works to gain the trust of students. (48) Blayney's comprehensive orientation presentation provides an overview of his department's services as well as work place safety information. He's enthusiastic about the opportunity to communicate with employees who have just started at Dartmouth, believing that "the optimal time to interact is when people are new." His studies have shown that the longer their time of service, the more difficult it is for individuals to change their work place behavior" (49).

Former Dartmouth students wrote about lab safety in response to the question "*Did you feel safe working with chemicals in the lab?*" "I felt safe; but in part because I didn't think much of it. I never handled anything toxic or dangerous to my health. I always wore gloves and there always people/grad students around". And, "Yes -- we were taught which chemicals were particularly dangerous (e.g., EtBr, sulfuric acid), so I remember being extremely careful with those. I was pretty cautious but I do remember that one of my friends splattered sulfuric acid on her face during orgo lab once-- yikes."

Leadership

Within the safety culture change process, there is a need for leadership alignment, throughout the layers of management, to be established. Leadership alignment occurs when there is consensus for the safety culture implementation strategy at various levels within the organization from lab groups to departments to upper management. Leaders must gather student perceptions to identify true alignment, assumed alignment, forced alignment, or skewed alignment around the direction and implementation of the safety culture change process (119). There is also internal leadership and external leadership.

Ideally, in the context of this investigation, leadership pertains to examples in the universities that stand out in terms of safety practice or departmental or administrative leadership who lead by example. The CHAS survey of academic laboratory safety culture reported that most common answer for the primary safety leader was the chemical hygiene officer (87). The chemical hygiene officer is not usually in the chain of management. Individuals, who by job classification or by position of responsibility, demonstrate leadership in the field of safety are good examples for this investigation. Due to the aim of this investigation, examples of faculty and EHS leadership will have to suffice unless an example of good safety leadership stands out.

UCLA

UCLA has shown leadership, externally and internally in the quest to improve safety in the wake of the recent accident. These efforts in leadership appear to have been lacking after the prior non-fatal accident cited by Cal OSHA. UCLA stands out in this arena because as a whole it has tried to take a leadership role in lab safety since the accident. The national leadership of the university is external and influential in the field of academic laboratory safety. "The accident was a huge wake-up call for UCLA and the Academic community" said Mark Hoover, a senior scientist at the National Institute for Occupational Safety and Health (NIOSH), "Many institutions might have had an initial response and then gone back to business as usual. There was a sense that someone needed to step up in fostering a more proactive approach, and UCLA, with a compelling story to tell, has taken on that leadership role" (34).

An example of UCLA taking the lead in safety is the establishment of the University of California Center for Laboratory Safety which was created in the wake of the accident. According to Mark Hoover, "The UC Center for Laboratory Safety is exactly what is needed to improve the ability of university students, faculty and staff to better anticipate, recognize, evaluate, control and confirm that their facilities and actions are adequate to safely manage the hazards they encounter" (34).

UCLA's leadership in safety extends to the Chancellor. EHS Director James Gibson says that "the biggest factor in changing the safety culture has been the direct and active role played by the chancellor and vice chancellor for research, demonstrating their commitment to laboratory safety at the university" (34). The staff representatives interviewed at UCLA agreed that the Chancellor has been a good advocate for safety (33).

Dr. Gibson is rather new in the role of EHS director at UCLA. He has the backing of the UCLA administration but his task is monumental. UCLA is huge with 4000 labs. It takes a huge effort to make significant changes to an entrenched system. Most of Dr. Gibson's current efforts are aimed at improving procedures such as training, inspections and PPE.

Northwestern

The ORS Department reported having good support but not necessarily leadership from the University administration. However, the 2010 accident gave the administration added incentive to be supportive. To ORS's delight, they received particular pressure from the Dean associated with the Chemistry Department to hire the chemistry-specific safety resource (Nick Waddell). This can be considered an example of the "catastrophe theory of institutional advancement", where accidents are catalysts for change (41).

Todd Leasia ran the NU ORS department for over 20 years. He retired in October, 2011. Many good developments for strong safety culture occurred on his watch. Under his direction, ORS developed the IRIS system to track inspections and training and fostered a mentoring policy, tracked chemical inventory and helped hire a chemistry-specific safety officer. Leasia's important role in ORS leadership was summarized in the Fall 2011 ORS Newsletter:

> *"During his 22 years as director, Todd has advanced the University safety program to the topmost level of compliance. His inspiring leadership has enabled ORS to receive numerous safety awards, implement ISIS, (the Integrated Safety Information System), triple the size of the department, establish a safety training program for the research community, develop an operations program to oversee waste management, and expand the biosafety, radiation safety, laser safety, and chemical and laboratory safety programs maintaining University compliance with federal and state safety regulations" (40).*

Joseph Hupp's actions in his NU lab post accident is another example of strong leadership and includes elements of trust and collaboration. His actions were aimed at restoring trust in his students. He presented information on these procedures to his colleagues in the chemistry department. He also reported that the ideas he used in designing these procedures were ideas he obtained through collaboration with colleagues (44). These leadership efforts were also described earlier in the PI accountability section.

Dartmouth

Michael Blayney has been the Director of Dartmouth EHS since 1997 and is a strong and seasoned leader. He had to reconstitute and shape the safety program from the beginning when he arrived and his experience was influenced by the accident. Dartmouth EHS and faculty under Michael Blayney's leadership led the way to reevaluate the hazards of dimethylmercury and glove safety. The experience of Karen Wetterhahn's death was a wakeup call which strengthened safety practice at Dartmouth and carried important lessons that still inform safety practices today. These include many of the procedures and values described in this report.

Leadership in safety and health at Dartmouth is all on Michael Blayney's shoulders (with assistance by his staff) and the university has long supported his efforts to shape and manage EHS safety efforts. Michael Blayney reports to the Provost and there has been long-term support for shaping the program in his image.

Student involvement

Safety culture means a focus on hazard identification and risk assessment, using formal tools, but also through a constant situational awareness (3). Michael Wright of the USW argues that "The way to build awareness is to involve students and lab workers -- the people most exposed to the risk – in that formal process of finding the hazards and assessing and addressing the risk. That's also the best method of education" (113). Studies have shown the benefit of employee participation in safety and health in industrial settings. Walters and Frick (173) listed the following features of effective employee/student participation: adequate training and information; opportunities to communicate with other students; channels for dialogue with management on existing problems and planned changes.

Student participation is a behavioral-oriented technique that involves individuals or groups in the upward communication flow and decision-making process within the university (174). The amount of participation can range from no participation, where the professor makes all decisions, to full participation, where everyone connected with, or affected by, the decision is involved.

UCLA

UCLA students do not participate in safety meetings or safety teams. There were no safety "teams" identified; only the UCLA Safety Committee that formed after the 2008 accident. The UCLA safety committee does not have any student representation. Inquiries about student or staff participation in safety committees yielded the information that one staff level person was allowed onto the UCLA safety committee. No students were invited (33).

Northwestern

Students at NU participate in safety committees. Students in the lab adjacent to the accident participated in hazard assessments and writing of SOPs for lab procedures. Between 25 and 30 students come from the research groups to monthly safety meetings (41).

Dartmouth

Students learn about safety precautions and safe lab practices, but not hazard assessment planning. There are graduate students who are T.A.s. Students do not participate in safety committees.

Table 40 presents a qualitative summary of how each case fared in the safety culture assessments. The table presents the list of safety culture values in the first column and the next three columns provide brief summaries of the actions taken by each university (discussed in this section).

Table 40 Safety Culture Value Assessment

Safety Culture Value	UCLA	Northwestern	Dartmouth
Management Commitment to Safety	Previously lab safety at UCLA was under the radar. The Chancellor is now supportive with increase in funding for creation of Center for Lab Safety. Despite budget constraints, UC System started lab safety institute and hiring staff. Recent changes have been made to administrative structure and to accountability for serious problems in the laboratory.	The NU Dean's Office of Arts and Sciences sponsored the creation of ISIS and the hiring of the chemistry safety officer. NU's safety practice is actually divided into three sections, the Office of Research Safety, the Risk Management Department and the Facilities Department. Lab safety, emergency and environmental management are handled separately from laboratory safety. This may not be the most effective way to manage all aspects of safety.	The accident at Dartmouth happened a long ago. According to Michael Blayney, funding and attention was paid to address the cause of that accident at the time(48). Dartmouth EHS has backup from the administration (48). There is a small EHS department. Dartmouth's safety department is also bifurcated. These divisions may make it difficult to coordinate all components of the safety culture model. In addition, the connection between the academic departments and some of the safety functions may be too tenuous.
Accountability: PI Responsibility/ Oversight	UCLA is taking steps but changes in PI accountability are not clear.	Accountability is spelled out at Northwestern. NU appears to have at least one PI that is willing to assume greater responsibility for the students in his lab. After the accident, the supervising PI instituted policy	Dartmouth reportedly has a handle on accountability through safety committees. (IBC, Chemical Safety, Radiation Safety, etc.)

		changes in the laboratory to reassure students. This amounted to an extraordinary effort made by PI post-accident.	
Accountability Sanctions/ Penalties	UCLA has policy 811, which means on paper a lab can be temporarily shut down for a serious violation. Although there is increased scrutiny on labs, there is no additional pressure on PIs to comply. Despite there being "many sticks, and not too many carrots". policies	NU called their policy the "Death Penalty" which is really a last resort. This is not a change from before the accident.	Dartmouth EHS can invoke sanctions by the dean. This has changed since the accident.
Collaboration	UCLA described collaboration between the provost, chancellor and EHS to improve safety after the accident.	At NU, collaboration exists within the ORS Department; some collaboration exists among researchers; collaboration exists between laboratories and ORS.	Dartmouth described EHS collaboration with faculty and Department chairs.
Transparency	UCLA has improved transparency by improving communications within the university community and in the greater academic safety community by providing resources and information about	NU ORS has an award winning newsletter published quarterly by the EHS department.	Dartmouth has a transparent web site with many safety resources. In addition they have Informative lab safety hangings for all labs. Dartmouth's website is extensive and easy to access and use.

	improved compliance in safety procedures. Website access to safety resources includes presentations and films on laboratory safety procedures.		
Trust	UCLA had mentors within some of the labs but it is not clear that that was a university policy. Undergraduate students reported feeling safe.	NU's mentoring program and the safety policies implemented in Hupp's lab after the accident was a great leap forward in instituting trust amongst students. Students reported feeling safe.	Dartmouth also mentioned trying to instill a safe environment at the outset of a student's career. EHS acts as a consultant on safety questions. Students reported feeling safe.
Leadership	UCLA is a leader some safety culture areas: in raising awareness of the issues and pushing procedures that will improve safety culture. UCLA stands out in its leadership efforts to improve laboratory safety. To a certain extent, this is risk management policy for the university to deal with its own safety deficiencies but to the extent to which it helps bring focus to laboratory safety issues in the greater academic community, all the better. From	NU displays excellent leadership in some safety culture areas including hazard assessment, student involvement, documentation, training, and mentoring. At Northwestern, Dr. Joseph Hupp took a leadership role in post accident lab management. He recognized that students were traumatized and acted to give them greater responsibility in managing their risks in the lab. This gave them greater comfort and knowledge of the hazards they faced. In addition, a list was made of chemicals that were off limits to	Dartmouth EHS and faculty under Michael Blayney's leadership led the way to reevaluate the hazards of dimethylmercury and glove safety. According to former Dartmouth students, lab safety is a priority, students felt safe, and many knew of Karen Wetterhahn's legacy, though it did not play a role that they could relate.

	accounts heard, Dr. Gibson's talks are influencing other academic institutions to reexamine their safety practices.	newer students. This too added comfort to their experience.	
Student Involvement	There is no student involvement at UCLA. UCLA students do not participate in safety meetings.	NU students participate in safety meetings; work together in safety teams on hazard identification.	Dartmouth graduate students act as TAs but students do not participate in safety meetings.

Result Summary

An interpretation of the information summarized in this results section is presented in the discussion section. It should be noted that in each case, regardless of the case performance on individual values, preliminary interviews with students found that they felt safe in the laboratories at the university they attended.

DISCUSSION

Summary of investigation

This investigation compares and evaluates the safety cultures of three academic institutions where laboratory accidents had occurred. The goal of this investigation is to examine the extent to which universities are motivated by academic laboratory accidents to improve their safety culture and how this impacts EHS practice and safety culture. A secondary goal is to investigate whether this impacts the academic community at large. Several developments have occurred since the beginning of this research in early 2011. At Northwestern, in October 2011, the long-time director of ORS, Todd Leasia, retired. The programs he spent years developing should remain in place but what will actually transpire is uncertain. During the preparation of this paper, the UC Center for Laboratory Safety was established and the significance of this institution is promising and welcome, but uncertain at this time. In an unprecedented development, the Los Angeles District Attorney brought felony charges against UCLA and Professor Harran on December 28, 2011, basing the charges on the Cal OSHA findings regarding the safety conditions and practice at UCLA that played a role in the fatal accident that took place there in 2008.

Comparison of Outcomes to Original Hypotheses

This investigation was performed using an academic approach, as described by Guildemund (2010). Fieldwork (visits to each campus) and ethnographical-inspired methods (including document analysis, observations, interviews, and correspondence) were used to carry out the investigation. The use of ethnographic research methods for assessment of safety culture is shown in recent research by Antonsen (2009)(81) and Guldenmund (2010)(137).

This investigation confirms the original hypotheses set out during the project. The original hypotheses of this investigation are summarized here.

- **An accident is an opportunity to innovate and improve safety practices within and outside of the university.**

This investigation confirms, on the basis of the cases examined, that accidents are unfortunate wake up calls. In each case studied, the accident ushered in improvements in EHS practice. Currently, with the accessibility of news and communication avenues, these accidents have an impact on other academic institutions as well. There is evidence that the UCLA accident and information made available by UCLA is causing other institutions to reevaluate their safety practices (139, 140). This research showed that the three universities took advantage of these accidents to implement changes to better safety their practices. In the case of UCLA and Dartmouth the accidents and changes made or being made thereafter are impacting safety practices at other universities.

- **The root cause of an accident is critical for evaluating the response on the safety practice and culture.**

The discovery of the problems that caused the accidents informed the quest for solving those problems. In the cases of NU and Dartmouth, the problems were incomplete or otherwise inadequate information. In both cases, steps were taken to close the information gap and improve the processes for obtaining information. In NU's case, this took the form of the added staff ORS member as a special resource for the chemistry department. In Dartmouth's case this meant research on the toxicity of dimethylmercury and updating the OSHA information about it. In addition, research was done on safety gloves, the limitations of protection and the safe use of them for research. In the case of UCLA, the myriad problems identified by Cal OSHA, highlighted the need to overhaul most of UCLA's safety practice and send out a call for upgrading safety practice in general. From this perspective, UCLA has a much greater task to improve its safety practice and culture than did NU or Dartmouth.

- **Two-way communication plays a significant role in laboratory safety culture.**

Communication is a tool integral to the safety culture and safety practice at any institution. Both external and internal communications were included in the model. The investigation showed that all three institutions used external communication to manage the aftermath of the accidents and that NU and UCLA continue to use it to exchange information and improve safety culture. Internal communication is good at all three institutions and represents a ready-made vehicle for promoting transparency and emergency communication.

The research found that transparent, two-way communication between students and PIs is a value-added procedure that is important to fostering trust in the laboratory environment. It is not enough to have good newsletters or a great website; avenues must be open for students to voice their concerns about hazards in the lab and to feel free to divulge that accidents or near misses occurred. This process fosters trust and contributes to safety practice. This is significant and something that should be striven for in a health safety culture. NU and Dartmouth encourage reporting incidents and near misses.

- **Existing regulations are too weak and ineffective to promote safety culture.**

As touched on at the beginning of this paper, there are gaps in OSHA coverage and other relevant regulations do not directly have jurisdiction over chemical management in laboratories. Other regulations may be examples of methods for regulations to be tightened. The CSB also brought up the role of granting institutions in requiring safe lab work. Perhaps regulations and guidelines governing biological and radioactive materials are examples of ways that laboratory chemicals could be better managed.

Management commitment to safety, as manifest in resources and administration support are critical components from which the safety culture values emanate. At UCLA, the renewed commitment of the UC administration to safety is manifest in several ways, not the least of which is the creation of the UC Center for Laboratory Safety.

Comparison to extant literature

This investigation makes a significant contribution to the safety culture literature, it especially fits in with studies that were done in retrospect after an accident. It is significant that not many safety culture evaluations have been done in academic institutions. This is one of the firsts. Guidenmund wrote in his 2009 PhD dissertation that genuine safety culture case studies were still quite absent from the literature and that it did not appear that that would change drastically in the near future (137). However, several recent surveys have been identified, including the NIST investigation (99) and the

CHAS survey of academic safety officers (87). The only examples of safety culture examinations of academic institutions found were Wu et al's studies on the effect of leadership on safety in Taiwanese universities reiterated the importance of strong leadership and management commitment to safety in the quest to change culture. Their studies were important contributions the understanding of the relationship of these values on safety because twenty-one accidents causing injuries and death to students and instructors occurred in Taiwanese university and college laboratories between December 1997 and May 2004 (116),(175, 176).

Key Findings - Safety Culture at the Three Universities

The safety practices of the three cases were assessed on the basis of their execution of procedures and accomplishment of the values in the model. Qualitative assessment of the practices was documented and summarized.

Summary of the Assessment

Tables 41 and 42 summarize the evaluation of each case in terms of their performance of safety climate procures and safety culture values. It demonstrates the difference in the model between procedures and values – safety climate procedures and safety culture values and assesses whether the changes in safety climate and safety culture were in place before or made after the accidents and whether they are successful. The charts are followed by an interpretation of the results of the analysis.

Table 41 Safety Climate Procedure Summary

Procedure Summary	UCLA		Northwestern		Dartmouth	
Procedure	Changed since accident	Positive or Negative or neutral	Changed since accident	Positive Neg. or neutral	Changed since accident	Positive or Negative or neutral
External Communication	YES	+ Multi-media blitz	NO – good program in place before accident	+	YES	+
Internal Communication	YES	No upward communication from students	YES	+ ISIS tracks training and inspections. Wiki site proposed	YES	+
Incident Reporting	YES	Formal program – no information on participation	NO- good program in place before accident	+ Formal program in place plus independent review	YES	+ No formal program reported. Reporting encouraged
Hazard/Risk Assessment	YES	Voluntary LHAT is macro scale only	YES	+	NO	None reported
Safety Committees	YES	No student participation	NO-in place before accident	+	YES	No student participation
Recordkeeping	YES	+Improved document-ation	NO- good program in place before accident	+	YES	+
Training	YES	+ Much improved training	NO- good program in place before accident	+	YES	+
Inspections	YES	+ Inspection process has improved in frequency	NO	+ Inspection procedures and	YES	+ Inspection procedures and tracking were set up

		and specificity		tracking were in place before the accident		since the accident
Hazardous Waste Management	YES	+ Waste handling procedures were in place before the accident. Added resources were made available since the accident.	NO	+ Waste handling procedure s were in place before the accident.	YES	+ Waste handling procedures were in place before the accident.
Emergency Planning and Preparation	YES	+ Emergency procedures were in place before the accident.	NO	NU Emergenc y response is decentrali zed. Not easily accessible	YES	+ Extremely comprehensiv e emergency response guide is accessible

Table 42 Safety Culture Value Summary

Value Summary	UCLA		Northwestern		Dartmouth	
Value	Changed since acciden t	Positive or Negative or neutral	Changed since accident	Positive or Negative or neutral	Changed since accident	Positive or Negative or neutral
Management Commitment to Safety	YES	+ Improved since accident	NO	Has been positive +	YES	+
PI Responsibility/ Oversight	YES	Unclear -	YES	+	YES	+
Sanctions /Penalties	YES	Unclear -	NO	Has been positive +	YES	+
Collaboration	YES	Unclear -	YES	+	YES	+
Transparency	YES	External + Internal	NO	External + Internal +	YES	External + Internal
Trust	NO	Policy Unclear. Students	YES	+ Students interview	YES	+ Students interviewed

		interviewed feel safe.		ed feel safe		feel safe
Leadership	YES	External + Internal+	NO	+	YES	+
Student Involvement	NO	None found -	NO	+	NO	None found -

UCLA

The UCLA accident has sent reverberations around the chemistry and academic safety communities, causing calls for renewed focus on chemical safety and academic laboratory safety in general. The accident appears to have been a catalyst for change of safety practice at UCLA. This has been facilitated by attention from Cal/OSHA, the CSB and Dr. Gibson's presentations in many forums. UCLA is attempting to lead the campaign for improvements in academic safety through these presentations. Improvement in communications and some procedures are helping UCLA to improve its safety practice but not necessarily its safety culture.

Procedure Assessment Summary

The charts in Tables 41 and 42 show that UCLA is making a great deal of efforts to improve safety climate procedures, the foundational elements to a safety laboratory environment. But they have made fewer successful efforts in the safety culture values. Most of UCLA's efforts to improve safety practice were started since the accident in 2007. This research shows that UCLA is successfully implementing four areas they have worked to improve since the accident: external communication, recordkeeping, inspections and training. These are the areas UCLA has targeted for improvement and not coincidentally, recordkeeping, inspections and training were also listed as deficient by Cal OSHA. UCLA was already managing hazardous waste disposal and emergency planning and response prior to the accident, as these are required by Federal law; though Cal OSHA cited UCLA for lacking hazard identification and improper storage of hazardous materials. These areas were probably improved after the accident, but they were present beforehand.

UCLA falls short in two procedures: Internal Communication and Hazard Assessment. In regard to communication, there is no avenue for upward communication from students to professors, EHS staff, or university leadership. The university also lacks student participation in safety committees. In terms of hazard assessment, despite the fact that LHAT is in place, it is voluntary and operates mainly at a macro scale. The LHAT system now in place seeks to identify hazards in the lab for EHS. It is not well suited to provide micro-scale information that could assist researchers and students to perform hazard assessments for individual experiments. This represents a troubling gap in the procedures adopted in the wake of the accident.

Value Assessment Summary

UCLA is not adequately addressing the majority of safety culture elements. There is improvement since the accident in leadership, both external and internal and management commitment to safety, as demonstrated by the Chancellor and EHS Director James Gibson. There has been a great deal of information disseminated both internally and externally since the accident. This is a concerted effort at targeted transparency. However, in the majority of safety culture values, the efforts are either non-existent or fall short. The chart above shows that UCLA falls short in:

PI Responsibility and Oversight, Sanctions and Penalties (Although UCLA reports that one lab was shut down using Policy 811) and **Collaboration and Trust** are areas that need work, as does **Student Involvement** in laboratory safety.

UCLA Summary

Although undergraduate students reported feeling safe in the UCLA chemistry labs, since the 2008 accident, UCLA has only begun to change what appeared to be grossly deficient procedures. They have taken steps to address the deficiencies sited by Cal OSHA, principally through improvements in management commitment to safety, external communication, training, inspections and recordkeeping. They have also started a Center for Laboratory Safety to research how to improve laboratory safety. However, no serious or meaningful effort to address safety culture value issues such as trust, student involvement or accountability including sanctions and penalties for non-compliance is apparent. This is particularly worrisome because UCLA failed to take actions to make corrections in procedures when prior non-fatal laboratory accidents occurred. Had corrections in safety practice procedures started earlier, perhaps the fatality could have been avoided.

Northwestern

The accident at NU was attributed by some of the NU interviewees to the "uncertainty inherent in chemistry". The accident revealed the fact that published studies may not include all the information one needs to prevent uncertain results. However, hazard assessments performed before an experiment can reduce the uncertainty in the procedures. As a result of the accident, performance of hazard assessments at NU increased through the work of both one of the PIs involved in the accident and though the safety officer dedicated to helping the chemistry department. These actions were not publicized but go a long way towards improving safety culture at NU and provide an example for other institutions to emulate.

Procedure Assessment Summary

NU had many safety climate procedures and cultural values in place prior to the accident. These include **external communications** – in the form of an award winning ORS newsletter and a targeted transparency program for releasing information as deemed necessary. A formal **incident reporting** program with independent review was in place, as were **safety committees** with **student participants, recordkeeping, training, inspections, hazardous waste management and emergency planning and preparation** ISIS is a means of **internal communication** that tracks training and inspections and communication with labs. Improvements in the area of internal communications were underway in the form of a wiki site for hazardous procedure information. Since the accident, **hazard planning and risk assessment** has taken on a new importance and Nick Waddell has facilitated this increased attention. . The decentralization of the safety functions, especially the isolation of the emergency planning and preparation was a concern for this assessment.

Value Assessment Summary

In the realm of safety culture, many components were in place before the accident and continued to be strong. These include **management commitment to safety, PI responsibility and oversight, sanctions and penalties, collaboration, transparency, trust, leadership and student involvement**. Of special note are Professor Joseph Hupp's actions in his lab after the accident to help his students to feel safe after the traumatic events that occurred and Nick Waddell's role as safety resource for the chemistry department. Trust amongst students involved was increased by these actions and added ORS staff presence.

NU Summary

NU has made minor changes since the 2010 accident, because their safety programs were basically sound. Only the diversification of safety functions into several offices is of concern, because of the potential issues of communication gaps and difficulty in coordinating of safety efforts. This incident may therefore reflect a case where bad outcomes are still possible even in an academic environment with a positive safety culture. Graduate and undergraduate students reported feeling safe in the NU chemistry labs.

Dartmouth

The Dartmouth accident sent reverberations through the chemistry community and the academic safety community when it occurred in 1997. Changes were implemented at Dartmouth and beyond because the accident exposed the insufficient knowledge of the level of acute toxicity and permeability of dimethylmercury. This discovery had profound effects on OSHA, and the agency revised the hazard information on the chemical, and on the study of appropriate PPE need to prevent exposure. Dartmouth's safety culture benefited from the accident in that it set a path of improvement which has been followed in the years since.

In the case of Dartmouth, the 1997 accident was a real catalyst for change. Most safety climate and culture elements are present at Dartmouth and were begun to be put in place at Dartmouth after the accident in 1997. Since the accident happened so long ago, the meaning of "changed since the accident" is slightly different than for the other cases which occurred more recently. There has been a much longer time for changes to occur in the aftermath of the incident.

Procedure Assessment Summary

Most of the procedures have been altered and put in place at Dartmouth since the accident in 1997. These include **communication, recordkeeping, training, inspections, hazardous waste management, safety committees and emergency planning and preparation.** One exception to this is **hazard/risk assessment**, which was discussed in the interview with Michael Blayney, but was not reported by undergraduate students to have occurred. In addition, although no formal incident reporting program was discussed, Michael Blayney has said that **incident reporting** is encouraged and that EHS works to instill a safe atmosphere for students. Students reported feeling safe in the labs.

Value Assessment Summary

Management commitment to safety, include **management commitment to safety, PI responsibility and oversight, sanctions and penalties, collaboration, transparency, trust, and leadership** are addressed by Dartmouth's safety practices and policies. A value which was not reported to be present was **student involvement** in safety, which also was not reported by undergraduate students to have occurred. The only example of student involvement is the presence of graduate student TAs who are reported to play a role in safety instruction in the laboratory. More information on their involvement in safety practice is needed to assess their contribution.

Dartmouth Summary

Dartmouth has made many changes in its safety practice since the 1997 accident. Michael Blayney reported that the safety program needed overhauling when he came on board just before the accident. He had just begun to understand that when the accident occurred. This event was a catalyst for many changes, including quite a few that were unanticipated. The insular nature of Dartmouth and the leadership of Michael Blayney have formed a unique safety environment that achieves many of the safety culture goals. Graduate and undergraduate students reported feeling safe in the NU chemistry labs.

Ideas for Improved Academic Safety Management

1. **Safety Culture is a useful concept for evaluating academic laboratory safety**

As shown in the literature review, there have been many articles and investigations but little consensus on safety culture and safety climate. This safety culture model combines several important aspects of academic safety practice and considers them vital elements of best EHS practice and the safety culture model. It highlights how management commitment is the bedrock of safety culture. Although portrayed statically, this model can also be thought of as a dynamic representation of how procedural elements interact with each other and with the culture values. This safety culture model fits academic safety environments and can be useful to assess and improve them.

While all might agree that safety culture is important, there is no evidence that a good safety culture prevents accidents. To be sure, a trusting and learning environment is a better environment to foster safe behavior.

2. The Safety Culture Model as an Assessment Tool

The model of academic safety culture procedures and values created for this investigation is a useful tool through which to examine how university safety practices are functioning and whether they are successfully achieving safety goals. The model was created through a review of the safety culture and safety climate literature. It consists of both procedures that are the foundations of safety practice in academic institutions and values which are behaviors and traits to strive for to create a safe and trusting learning environment. The benefits of this model are that all the procedures are described and prescribed by the OSHA laboratory standard (104) and Prudent Practices (1) and the safety culture values were obtained from the safety culture literature sources such as Reason (85), Havold (177) HSE, NRC (178, 179), (116). The elements of the model were reviewed by academic safety professionals for completeness and relevance. Of course the procedures can be done without the values attached to them but that is only a partial attempt at safety culture.

3. Safety Climate Procedures and Safety Culture Values

As shown by this research, two types of safety concepts are critical to the idea of safety culture in academic laboratories. Both are important contributory elements in their own right and influence each other. Safety climate procedures are the easiest to achieve, but the mere achievement of them does not constitute “a healthy safety culture”. Safety culture values are more behavioral and belief based and may be harder to achieve without management commitment to safety. Michael Blayney argued: "Training alone in the absence of a viable safety management function is not going to do any good because there's nothing there to help facilitate people." Strong leadership is evident in all three cases but not all have achieved a safety culture.

This investigation showed that some universities have achieved a wealth of safety culture (NU and Dartmouth), and yet as shown in the case of NU, even a pretty comprehensive program can experience an accident. In the cases of Dartmouth and NU, insufficient chemical information was a cause of the accident. In the case of Northwestern, it was insufficient information about an experimental procedure. In the case of Dartmouth, it was insufficient information about the toxicity of dimethylmercury. In both situations, steps were taken to remedy the insufficiencies, to fill gaps in chemical and chemical procedure information. Both remedial approaches changed safety practice and brought their safety programs closer to a healthy safety culture. They did not have far to go to achieve this.

In contrast at UCLA, there is just a modicum of safety culture, mostly based on efforts made since the accident. There is management commitment but at this point they have managed to address procedural shortcomings. Attempts to improve culture have had unclear or non-existent results. UCLA has a long way to go to achieve a healthy safety culture.

Attempts to generate safety culture metrics will most likely only be applicable to procedures. These are elements of the model that can be macro-scale and can be quantified. In contrast the safety culture values must be evaluated qualitatively, as has been done in this investigation. Both types of evaluations are valuable and should be utilized in this type of assessment.

4. An Increased Role of Regulations and Guidelines

Problems with chemical management were causal factors in the accidents. Two suggestions arise from the regulatory research for improving chemical management. One idea is to create chemical regulations similar to those that regulate radioactive materials. Another is to modify NIH guidelines for chemical management. In this scenario, NIH guidelines could be studied to investigate how they could be modified to improve management of laboratory chemicals.

For example, under NIH guidelines, experiments involving recombinant DNA are classified into six categories, based upon the number of regulatory hurdles they are required to clear to receive approval. The most dangerous experiments require IBC (Institutional Biosafety Committee) approval, RAC (Recombinant DNA Advisory Committee) review *and* NIH director approval prior to initiation of a proposed experiment. Non-exempt experiments considered the least dangerous only require IBC notice which can be given *simultaneous* to initiation of the proposed experiment (180).

Experiments with chemicals could be classified into hazard categories, and these categories could be assigned regulatory hurdles they are required to clear to receive approval. The most dangerous experiments could require ICC (Institutional Chemical Safety Committee) approval, *and* granting institution approval prior to initiation of a proposed experiment. Experiments considered the least dangerous could only require ICC notice which can be given simultaneously to initiation of the proposed experiment (180). The Department of Homeland Security (DHS) Awareness and Localization of Explosives-Related Threats (ALERT) program at Northeastern University has an extensive safety program (181). Much grant money that sponsors goes through granting agencies such as the National Science Foundation (NSF), NIH, and DHS. These agencies could be enlisted to tighten up safety requirements to obtain and maintain grants.

In an academic environment one crucial population of stakeholders is only on campus for a short time (four years). Freshman or sophomores today would have no knowledge of accidents that occurred in 1997, 2007, or 2010. The Clery Act (34 C.F.R. 668.46) is a federal regulation that requires all colleges and universities that participate in federal financial aid programs to keep and disclose information about crime on and near their campuses. Information of this type is supposed to alert prospective families of safety issues at the campuses where their child may attend college. If an accident changes the safety practice and culture of a university, it should also be divulged to potential students.

5. Safety teams involving students

Safety committees have become a standard feature of workplace safety programs in many industries and sectors. For safety committees to function on a micro-scale and to help exchange information between laboratories, they should have student and laboratory staff members. These committees should have real power to implement change. Research has shown that safety committees with students and staff involved promote trust, and safety culture (135, 149). Good functioning safety committees are department-specific committees, have regular meetings with representatives from laboratory groups, include content like discussions of accidents or near misses, and student involvement in them. This value promotes safety culture and trust.

Strengths and limitations of the study

Strengths of this investigation

Three cases were examined in this investigation. The investigation followed an established procedure for safety culture assessments. Personal interviews were conducted with key stakeholders at each university. Literature on the accidents and safety culture was available. A safety culture model was created from the literature. The safety culture model was vetted with safety practitioners in the field. Interviews were triangulated with EHS directors, faculty and students.

Limitations

Safety climate research on procedures can be quantified (e.g., rates of training and inspections) But there are no quantitative metrics against which to evaluate the safety culture values. Further investigation must be conducted through interviews with students and staff in order to characterize the safety culture.

There is increasing evidence, based on meta-analytic reviews, that safety culture (i.e., workers' shared perceptions measured by means of questionnaire surveys) is a predictor for safety performance, and this across industries and countries (70, 182).

Potential Bias

A potential bias of this investigation was a focus on the EHS department and staff as opposed on students. Interviews were conducted with EHS employees and staff, and one long interview was conducted with a NU student. Other students were emailed short lists of questions. Emails with other students hinted at how the efforts of EHS are perceived. More work could be done in that area. Future work could refocus the investigation on student perception and include focus groups of students.

Representativeness, generalizability

The fact that safety culture can be regarded as a predictor for safety performance, is appealing, as this can form a basis for a more proactive approach toward OSH - i.e., taking preventive actions before work related accidents actually occur. Model and methods used in this investigation are suitable and applicable for any academic institution. Model is suitable for any academic institution. This type of safety culture model could be used to evaluate the safety culture of other institutions before accidents happen. The model is in line with other safety culture models.

Future research needs

Filling the information gap – Insufficient information about the chemicals being used in the laboratory and/or the procedure, played a role in two of the accidents (Dartmouth and NU) An innovative solution to this dilemma was suggested by the NU ORS staff. This entailed putting together a "wiki" website that would accessible to chemistry students with answers to procedural questions, and to which students could add questions or leave information found in inquiries about chemicals or procedures. This would be a valuable resource for upwards communication for the NU chemistry students. This type of resource could be made available to universities in general to reduce the uncertainty usually attributed to the "randomness of chemistry".

Uneven regulatory coverage -This investigation pointed out the need to fill holes in regulatory coverage of chemical use at academic institutions. Interested parties should be enlisted to help generate this kind of data. These entities include granting institutions and federal regulatory agencies that have interests in chemical management, OSH, hazardous waste, and waste minimization; such as NIOSH, OSHA, DHS, NSF, EPA, and RCRA.

Use of the Safety Culture Model -This investigation experimented with the use of a safety culture model derived for academic institutions. It could be very useful to academic safety culture research in the future to use a framework like this to evaluate other institutions. However, it would also be helpful to standardize metrics with which to measure the safety climate elements. Safety culture investigations of the future must include more extensive interviews with students and staff. In the future it may be possible to write a prescription for a healthy safety culture based on a safety culture framework.

Conclusion

In the past few years, there were major laboratory accidents at a number of academic labs including Texas Tech, Yale University and Boston College. These accidents underscore the need for revitalization of academic laboratory safety. This investigation serves as a comparative examination of safety cultures at a specific point in time at three universities and suggests the opportunities and obstacles for improving safety culture. The Safety Culture Model is a useful tool that can be used to assess the progress of reducing health and safety risks for students and staff in academic laboratories. Science involves the creation of new knowledge, inherently exposing those who undertake research to new and unknown risks. Academic laboratories must be vigilant in assuring that the practices and values that are used to protect workers and students doing that work evolve and develop alongside those new discoveries.

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OVERALL CONCLUSION
INFORMATION, COMMUNICATION, AND CULTURE IN ACADEMIC CHEMICAL MANAGEMENT

The objective of this dissertation is to understand factors that affect the adoption of chemical management policies in academic laboratories ranging from reduction of wastes through chemical surplus sharing (CSS), provision of health and safety information through web-based sources and creation of safety cultures in response to accidents. The research in this dissertation seeks to provide information and tools to improve chemical management and health and safety in academic laboratories for environmental health and safety practitioners, managers, and for policy makers concerned with these issues. The information gathered has been analyzed with this audience in mind. As such, the research papers provide information on innovative programs and practices and effective policies and how these might be applied to academic laboratory environments to improve chemical management and health and safety.

The first paper explored university chemical surplus sharing programs; how they are implemented and what makes them a success. The second paper explored alternative web-based chemical health and safety information as resources for researchers and students in university laboratories. The third paper explored university laboratory accidents using the concept of "safety culture" as lens through which to observe the impacts on safety practice. Through this exercise, a safety culture model was created with the major value and procedural elements of prudent practice in the academic laboratory. Each of these papers provided tools aimed for improving chemical safety in academic laboratories.

The research investigated several significant factors that influence chemical management and health and safety in academic laboratories. Communication, information, and culture play critical roles in university laboratories. Exchange of information facilitates best practices such as waste minimization, assessment of hazards and promotes safety culture. The dissertation research explored how information can modify the way activities such as purchasing, hazard identification, and training are traditionally done, and how information can impact chemical management policies, worker/student understanding of risk, and overall safety culture. The research suggests that management commitment to safety overrides all of these factors.

Themes: Communication, Information and Safety Culture

In carrying out this research, three general themes emerged: communication, information and culture. University laboratory safety is dependent on the quality of information available, the success with which it is communicated and the culture in which it is received. The first paper examined how effectively information can be communicated to promote waste minimization while the second paper considered the quality of safety information in terms of its embeddedness and the third considered the culture of safety as a determinant of responses to accidents. Findings in each area are described in the following section.

Communication

Communication plays an essential role in the chemical management and health and safety in academic laboratories. Communication in the form of advertisement and surplus chemical websites play critical roles in the success of chemical surplus sharing programs. Marketing and advertisement were found to be essential to attracting interested participants in chemical surplus sharing, to create a ''buzz'' around sustainability and waste minimization. The limitations of Material Safety Data Sheets in providing useful risk communication requires workers and students to find other sources of chemical information, usually on the web. This provides its own challenges.

Communication is also a critical element of safety culture. There are two categories of communication in an academic environment, internal and external communication. External communication can promote safety through information sharing. Information sharing was witnessed in the aftermath of the lab accidents investigated. Reaching out to the public can promote improvements in safety practices in the greater academic community, but may not promote internal safety culture.

One reason for this is that internal communication must flow both ways to promote a strong safety culture in an academic environment: up from the students and down from the administration. In many cases students may be too intimidated to voice fears or concerns in the laboratory, requiring other avenues to be opened to encourage discussions and inquiries about safe practices. The absence of communication channels can be readily perceived. However, the presence of communication does not assure its quality or reliability, nor trust in its veracity. To account for this, safety culture investigations in academic institutions must employ interviews of students and staff.

Information - Forms and Sources of Information

Chemical information in the right form, place, and time can promote waste minimization and hazard identification. Chemical inventory systems can play an important role in comprehensive chemical management. But this requires it to be up to date, accurate, and easily accessible to promote chemical surplus sharing. Longevity of CSS programs depends on the adequacy and not simply the presence of an information system.

The rating of risk information provided through websites depended on users perceptions of its relevance, compatibility and accessibility. In order to be accessible and embeddable to students and laboratory workers, chemical safety information must be in the right format, in the right place, at the right time. Future use of those websites was predicted by these factors in all case accept for Google. The use of Google as a search engine to provide chemical information is a cultural phenomenon. Given its predominance, Google search routines influence the way laboratory personnel research, buy and handle chemicals. Sources of chemical health and safety information sources must recognize the role of Google in guiding the search routines of their target audience.

Safety Culture and Management Commitment

The culture within a department and within a laboratory greatly influences safety practices experienced by students and workers. Two types of safety concepts were found to be critical to the idea of safety culture in academic laboratories. These are safety climate and safety culture. Both are important and influence each other. Safety climate procedures are the easiest to achieve, but they alone do not constitute "a strong safety culture". Safety culture refers to a commonly shared, stable set of practices in which members of an organization learn from errors to minimize risk and maximize safety in the performance of organizational tasks and the achievement of production goals(1). The safety culture of an organization acts as a guide for how employees will behave in the workplace(2). Safety culture determines the commitment to and the style and proficiency of an organization's health and safety programs. If a strong safety culture is not present even the best safety management practices will not function effectively. An ideal safety culture propels the organization system toward the goal of maximum safety and health, regardless of the laboratory culture or the leadership's personality(1).

Superseding these factors is management commitment to safety, which affects and transforms all efforts towards a strong safety culture. Strong leadership is needed to achieve a strong safety culture. The position and organization of the safety function in a university influence safety practice and culture. This is manifest in at least two ways. For the department to run effectively and fulfill its safety function, it must have support and commitment and a connection to the university administration and a physical proximity and political connection the administration of the science departments. This is important for university science departments and labs where safety rules are often seen as being "in -the- way" and PIs may be resistant to EHS staff. In addition, the many aspects of the safety practice are best handled under the auspices of one EHS department in order to facilitate communication between functions, including emergency, biosafety, chemical safety and radiation safety. Decentralized functions may lead to ineffective and inefficient safety practices.

The hierarchical relationships of personnel within a lab may contribute to accidents and near misses. Within most academic science laboratories, the PI is supposed to be responsible for compliance with EHS regulations and good practices. This may not always be the case. In some circumstances, the PI may appoint a safety officer to assist in meeting his or her safety responsibilities. In addition, the PI is ideally responsible for registering assigned spaces where hazardous and/or regulated materials or equipments are used and stored, ensuring that all laboratory or facility personnel under his or her supervision are trained, and that inspections are conducted to meet EHS requirements(1). Lack of recognition of the greater power of PIs in a lab, may lead safety culture advocates to fail to recognize the diminished power of those in subordinate positions. Dysfunctional safety consequences are often the result of the hierarchical credibility gap that derives from stratification of personnel. Lower level staff often keep track of critical information and are unable to persuade higher-ups in the organization to make changes based on their knowledge (3). This may cause lab accidents to happen because students are afraid to speak up.

Policy Implications

From the government's perspective, laboratory educational institutions are notoriously difficult to regulate. Existing regulations do not adequately regulate chemicals in academic laboratories and do not protect students in academic laboratories. Not only do they enjoy an unusual degree of autonomy, but the vast range of activities and dispersed authority create seemingly intransigent obstacles to regulation, especially environmental and workplace safety regulations that were designed primarily for mass production industries (1). OSHA's jurisdiction in academic institutions is limited. RCRA regulations mainly pertain to hazardous waste management and disposal and therefore apply to laboratories only tangentially. Regulations play a much more direct role in biological laboratories and those that use radioactive elements and lasers. This research found ample room for new and improved guidance and regulations to bring about improvements in chemical health and safety management in academic laboratories.

Improve accessibility and quality of web-based chemical hazard and toxicity information available to laboratory personnel

For academic laboratories in particular, information critical to safe handling and management of chemicals is needed. Embedded web-based information could be an enhanced safeguard and promote safe handling of chemicals. According to the second research paper, web-based resources need to be embeddable in addition to being high on the Google hit list. Google plays a major role in chemical information searching because it is so accessible and fast. It has addicted users to quick results regardless of relevance, and compatibility. The following suggestions address specific information needs of students and staff in academic labs:

- Establish a lab culture which allows time for more effective searches for chemical information; one which exhibits concern for an understanding of chemical toxicity, and encourages communication between safety professionals and lab personnel.
- Teach students how to find useful web-based information on chemical safety, toxicity and handling, by going beyond a simple Google search through introduction to alternative resources such as those tested in Paper 2.
- Encourage chemical information web sites that make use of Google's Page Rank Algorithm to obtain a high rank in a simple Google search. Chemical websites with useful information should learn lessons from Google and adapt their sites in light of this dominant search reality.

Improve understanding of safety culture

This investigation found that safety culture and safety climate research are useful lenses through which to investigate safety practice in academic institutions. The distinction between safety climate procedures and safety culture values is important because it may be possible to establish metrics for procedures like inspections and training, but it is much harder to measure trust and leadership. It was shown in this research that the safety climate procedures at an academic institution are the first steps towards safety culture. Further, the investigation of safety culture must included ethnographic research such as interviews and focus groups. It cannot be measured solely by statistics, but requires qualitative assessments of management commitment, values and practices. These tools should be employed to improve safety culture in academic laboratories.

Improve regulations or guidelines

To assist with better management of chemical health and safety improved regulations or guidelines were found to be needed in the following areas. These recommendations are for policy makers concerned with improving chemical management at academic laboratories.

Encourage chemical inventories and chemical surplus sharing

Chemical regulations and guidelines should more explicitly compel tracking of chemical inventories and sharing of chemical surplus to minimize hazardous waste generated by academic laboratories. Right now there is no consistent regulatory requirement to track inventory. Tracking chemical purchases, ownership, and disposal in chemical inventories are a crucial part of chemical management. They also play an important role in chemical surplus sharing. Tighter central controls on chemical purchasing might even improve efficiency to the point that the amount of available surplus is reduced. This would reduce both the costs of chemicals for the laboratories and the cost of waste for the universities.

Tighten up academic chemical management through improved guidelines or regulations.

Improved chemical regulations similar to those that regulate radioactive materials should be created. A related recommendation is to modify NIH guidelines for chemical management. In this scenario, NIH guidelines could be studied to investigate how they could be modified to improve management of laboratory chemicals. Experiments with chemicals could be classified into hazard categories, and these categories could be assigned regulatory hurdles they are required to clear to receive approval. The most dangerous experiments could require ICC (Institutional Chemical Safety Committee) approval, *and* granting institution approval prior to initiation of a proposed experiment. NIH Guidelines were discussed previously in Paper 3(4).

Fill gaps in OSHA coverage to include students and all university employees.

The following chart portrays the coverage academic labs by OSHA. Notably missing is coverage of students and public employees (in states with no state OSHA program). This recommendation requires a legislative change, which is unlikely in the foreseeable future. So for now, it makes sense to follow the lead of the Chemical Safety Board who recommended working with granting agencies and trade groups like the American Chemical Society to make changes to policies and guidelines to improve safety practice (5).

Regulation	Private Student	Public Student	Private Employee	Public Employee
Federal OSHA			X	
State OSHA (where available)			X	X

One example of an interim approach is EPA's modification to RCRA. Recently, EPA added Subpart K to existing RCRA Regulations. This new regulation is applicable to eligible colleges and universities and teaching hospitals and nonprofit research institutes that are either owned by or formally affiliated with a college or university. The alternative set of regulations allows eligible academic entities the flexibility to make hazardous waste determinations in the laboratory; at an on-site central accumulation area; or at an on-site treatment, storage, or disposal facility (TSDF)(6). This type of "special" regulation could be established for chemical management and health and safety in colleges and universities as well.

Conclusions

The research in this dissertation has provided information and tools for environmental health and safety practitioners, managers, and for policy makers to improve chemical management and health and safety in academic laboratories. Academic institutions face complicated chemical management issues. Communication policies, information management, and safety culture play critical roles in the university laboratory workplace. Maintaining a safe learning environment for students must be a top consideration of academic administrations. This research on chemical management reveals the importance of information and culture in the conduct of safety in academic environments. It shows that information and management commitment to safety culture plays a critical role in managing chemicals and environmental health and safety in academic environments and insuring that the pursuit of scientific knowledge does not come at the expense of workers' and students' wellbeing.

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5. U.S. Chemical Safety and Hazard Investigation Board. Texas Tech University Laboratory Explosion. Washington, D.C. ; 2011.

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APPENDIX A

CHAPTER I

SURPLUS SHARING QUESTIONS

IRB Application Number: 09-118-GEI-XPD

Ken Geiser/ Miriam Weil

Surplus Sharing Investigation:

We propose to identify 15 to 20 colleges and universities that can relate their experiences with surplus chemical sharing programs that their institution has tried or is trying currently. These interviews will take place over the telephone, although a list of some questions might be sent via email.

Here is the preliminary list of questions about surplus sharing;

General Questions:

Contact name:

Institution name

Location

Size of institution (number of undergraduates/graduates)

Public or private

How many research labs?

Who orders the chemicals?

Does the institution have central purchasing?

Have you tried a surplus sharing program?

Is it ongoing or abandoned?

Is there a chemical inventory? Is it kept up to date?

How many people work on chemical inventory?

Questions about Program

Is the surplus sharing program a formal/informal program?

How many departments/laboratories participate? (%)

Is the surplus sharing program supported by the administration?

How?

Is the surplus sharing program supported by the science departments?

How?

How does the program work? Describe briefly?

Is there a physical space for storage of surplus?

Is there a Website?

How are surplus chemicals gathered?

How are chemicals disposed of?

Are opened bottles shared, or only unopened ones?

How many staff members are involved? What are their roles?

Are there any monetary charges involved in the process?

How long are surplus chemicals kept around before they are disposed of? Who pays for disposal? Is it eventually charged back to the lab that abandoned the chemicals?

Success or Failure of program

Financial impact of surplus sharing? Money saved?

How many units are/were shared per year?

How many open bottles are disposed of per month?

If the program is considered successful, what factors contribute to the success?

If the program is not successful, what factors contribute to the failure?

What changes could be made to the program to make it (more) successful?

What factors are critical to the program's function?

How important is communication? (not important, marginally important, important, very important)

How important is the website? (not important, marginally important, important, very important)

What are the problems with the program?

Who are the main proponents of the program?

Is the administration in favor of the program?

Are the students in favor of the program?

Are the PIs and laboratory staff in favor of the program?

APPENDIX B

CHAPTER II- PARTICIPANT RECRUITMENT FORMS AND TRANSPARENCY QUESTIONNAIRE

PARTICIPANT RECRUITMENT FORMS
RESEARCH HELP WANTED – INVITATION

We invite you to participate in a research project to investigate the usefulness of web based chemical hazard information. You will be asked to complete a short computer exercise, a brief questionnaire, and a brief follow up interview. The interview will be audio taped. You will receive a $25 gift card for completing the project.

Participation is voluntary. It is your choice whether or not to take part in this research. If you have any questions, you may contact Miriam Weil at -----------.

If you would be interested in participating in this study, please answer the following questions and provide the requested information so we can contact you if you are eligible. The project may take one hour. Please send the completed forms to Miriam Weil at weilmirweil@gmail.com by November 19, 2010.

Thank you,

Miriam Weil

Do you have access to and use a computer at work or in the lab?

YES ☐ NO ☐

Do you come in contact with chemicals during work?

YES ☐ NO ☐ If no, please stop. Thank you for your time, but you are not eligible for this study.

If you came in contact with a chemical that you were unfamiliar with (cleaning material or a chemical) where would you be most likely to look for information on that chemical?

Pick one or two (label 1, 2).

Supervisor ☐

Co-worker ☐

MSDS ☐

Info on label ☐

Computer Web-search ☐

Other- search ☐

How often do you use a computer at home?

Never ☐

Few times a week ☐

Daily ☐

How often do you use a computer at work?

Never ☐

Few times a week ☐

Daily ☐

SIGNUP- Please write down at least your name and phone number on this sheet.

Name:

Cell Phone:

Home Phone:

Job/Lab Location:

Email Address:

Days and hours could you be available:

Please send this form to Miriam Weil at weilmirweil@gmail.com.

Thank you,

Miriam Weil Doctoral Candidate UMASS Lowell

2. Draft Script March 5, 2012 Group 1: Students+Techs

Transparency Investigation Background Information (can be read by the subject): The goal of this investigation is to test the utility of several websites for providing chemical toxicity information for people who work in and around laboratories. The experiment will measure this characteristic based on certain features of the websites that are criteria for embeddedness of the information. This survey is directed at technically educated people: people who have at least a bachelor or masters degree in science and who come in contact with chemicals in a laboratory setting such as laboratory technicians or graduate students. The criteria for the evaluation are relevance, compatibility and accessibility, which will be evaluated using the following types of questions:

Relevance:

How does information on these chemicals affect you? Your health? Your safety? The lab? Your co-workers? Your family? Why is this important to you? What is the impact of the information on your daily life? Is it clear what should be done with the information?

Compatibility:

Is the information compatible with your language and culture? Is the language clear and understandable? Are clear connections made between chemicals and health effects? Are those connections explained adequately?

Accessibility:

Is the website easy to find? Is the information well-organized? Does it come up when a chemical or health effect is searched? Is it available at the time you need it?

IRB Number: 09-118-GEI-XPD UML

A. TRANSPARENCY QUESTIONNAIRE

Preliminary Questions
Initial Profile Questions (pre-test).

F or M

Age

Level of Education

Years of School

School attended

Degree

Major Subject

Employment

Employed?

Job title

Location

If lab, what type?

Chemical Safety Familiarity

Does your work in the lab require contact with chemicals?

Does your work in the lab involve finding information about health conditions related to chemicals?

Do you ever look at Material Data Safety Sheets (MSDS)?

Do you know where to find MSDS for chemicals in the lab?

Have you heard of Acetone or Nitric Acid?

Have you ever looked at health and safety information about either one?

Internet Use

Do you enjoy searching for information on the internet?

Do you use the internet regularly?

Have you ever used the internet find information about a disease or chemical?

If yes, where did you look?

II. COMPUTER EXERCISE

Website Analysis

For each of the next two questions below we want you to try to search using google.com and then each of the five other websites to see if you can find useful information to answer the questions.

Please try the search using each website and rate the search experience of each one using the criteria described above and in the chart below. Keep track of the information you obtain from each website and document your impressions of each website. The rating scale and charts are provided to the subjects to rate the websites. The questions will guide the ratings.

Group 1: Question 1:
A lab protocol involves ethylene glycol. You worry that it might be hazardous and you want to look up the chemical hazard information. How can you find out about the potential health effects and whether there are alternatives to use?

I understand this question.

Check these websites to see if you can find the information and rate your experience. Keep track of the information you obtain from each website and what your impressions are of each. Try the search using each website and compare the search experience between the websites.

Google. www.google.com

CHE= http://www.healthandenvironment.org/tddb

EWG= http://www.ewg.org/chemindex

ATSDR= http://www.atsdr.cdc.gov/toxfaqs/index.asp

or http://www.cdc.gov/niosh/topics/chemical-safety

NJ=
http://web.doh.state.nj.us/rtkhsfs/factsheets.aspx?lan=english&alph=A&carcinogen=False&new=False

NLM= http://toxtown.nlm.nih.gov/text_version/chemicals.php

International Chemical Safety Cards: http://www.cdc.gov/niosh/ipcs/icstart.html

Relevance

Please fill out the following table. Rate the relevance of each website towards pursuing the problem using the following rating scale for each of the questions:

Disagree strongly,

2 Disagree,

3 Neither agree nor disagree

4 Agree

5 Agree strongly

Enter the number closest to your opinion into the corresponding box.

1.1.A.	Google	CHE	EWG	ATSDR	NJ	NLM	ICSC
A. The information is relevant to you.							
B. You can relate the information to your daily life.							
C. It is clear what should be done with the information.							
D. Information on the website is specific to the situation you are concerned about.							

Compatibility

Please fill out the following table. Rate the compatibility of each website towards pursuing the problem using the following rating scale for each of the questions:

Disagree strongly,

2 Disagree,

3 Neither agree nor disagree

4 Agree

5 Agree strongly

Enter the number closest to your opinion into the corresponding box.

1.1.B.	Google	CHE	EWG	ATSDR	NJ	NLM	ICSC
E. The information on the website was compatible with your language and culture.							
F. The information on the website made sense to you.							
G. The language used on the website was clear and understandable.							
H. Clear connections were made between the chemicals and health effects							

on the website.							

Accessibility
Please fill out the following table. Rate the accessibility of each website towards pursuing the problem using the following rating scale for each of the questions:

Disagree strongly,

2 Disagree,

3 Neither agree nor disagree

4 Agree

5 Agree strongly

Enter the number closest to your opinion into the corresponding box.

1.1.C.	Google	CHE	EWG	ATSDR	NJ	NLM	ICSC
I. The information on the website was in a place that was easy to find.							
J. The information was well-organized on the website.							
K. The information on the website is arranged in a way that							

suits your needs.							

Comments or notes about this question? Write them here.

2. **Group 1 Question 2:**

After working in a certain laboratory, your colleague has noticed that your face is flushed and you have started feeling nauseous and short of breath. You have noticed that a chemical called acetonitrile is on the bench in the lab and looks like it was not closed properly and may be leaking. Could it be causing those symptoms? Are these symptoms something to be concerned about? What should you do about it? Since the bottle looks leaky, how do you handle it and store or dispose of it properly. The MSDS does not help with these questions.

I understand this question.

Check these websites and see if you can find the information you want and rate your experience by answering the questions below. Keep track of what information you obtain from each website and what your impressions are of each. Keep track of the information you obtain from each website and what your impressions are of each. Try the search using each website and compare the search experience between the websites.

A.Google. www.google.com

CHE= http://www.healthandenvironment.org/tddb

EWG= http://www.ewg.org/chemindex

ATSDR= http://www.atsdr.cdc.gov/toxfaqs/index.asp

or http://www.cdc.gov/niosh/topics/chemical-safety

NJ= http://web.doh.state.nj.us/rtkhsfs/factsheets.aspx?lan=english&alph=A&carcinogen=False&new=False

NLM= http://toxtown.nlm.nih.gov/text_version/chemicals.php

International Chemical Safety Cards: http://www.cdc.gov/niosh/ipcs/icstart.html

Relevance
Please fill out the following table. Rate the relevance of each website towards pursuing the problem using the following rating scale for each of the questions:

Disagree strongly

2 Disagree

3 Neither agree nor disagree

4 Agree

5 Agree strongly

Enter the number closest to your opinion into the corresponding box.

2.2.A.	Google	CHE	EWG	ATSDR	NJ	NLM	ICSC
A. The information is relevant to you.							
B. You can relate the information to your daily life.							
C. It is clear what should be done with the information.							
D. Information in the website is specific to the situation you are concerned about.							

Compatibility
Please fill out the following table. Rate the compatibility of each website towards pursuing the problem using the following rating scale for each of the questions:

Disagree strongly

2 Disagree

3 Neither agree nor disagree

4 Agree

5 Agree strongly

Enter the number closest to your opinion into the corresponding box.

2.2.B.	Google	CHE	EWG	ATSDR	NJ	NLM	ICSC
E. The information on the website was compatible with your language and culture.							
F The information on the website made sense to you.							
G. The language used on the website was clear and understandable.							
H Clear connections were made between the chemicals and health effects on the website.							

Accessibility

Please fill out the following table. Rate the accessibility of each website towards pursuing the problem using the following rating scale for each of the questions:

Disagree strongly

2 Disagree

3 Neither agree nor disagree

4 Agree

5 Agree strongly

Enter the number closest to your opinion into the corresponding box.

2.2.C.	Google	CHE	EWG	ATSDR	NJ	NLM	ICSC
I. The information on the website was in a place that was easy to find.							
J. The information was well-organized on the website.							
K. The information on the website is arranged in a way that suits your needs.							

Comments or notes about this question? Write them here.

B. Follow up Interview Questions

1. Could you imagine looking for information like the hypothetical problems presented?
2. Will the information you found change your behavior or use of a chemical or product?
3. Now that you know about these websites, are you likely to use them again to answer questions about chemical hazards?
4. What made websites most helpful?

5.	Characteristics	What was the best website in terms of these features?
	Representativeness	
	Compatibility	
	Accessibility	

6. Which ones might you revisit? (check all that apply)						
Google	CHE	EWG	ATSDR	NJ	NLM	ICSC
7. Which website was most helpful overall?						
Google	CHE	EWG	ATSDR	NJ	NLM	ICSC

Thank you for your help with this project.

APPENDIX C

CHAPTER III - PROPOSED QUESTIONS ABOUT ENVIRONMENTAL HEALTH AND SAFETY PRACTICES FOR UNIVERSITY PARTICIPANTS

QUESTIONS FOR NORTHWESTERN PARTICIPANTS

Introduction/Background

The goal of these questions is to find out what has gone on since the accident in December 2010 to improve laboratory safety at Northwestern and how effective the measures are at addressing laboratory safety practice.

Questions for the NU Executive Director Office of Safety:

1. Background of the participant

2. Root Causes of Problem

What do you think were the main safety problems that needed correction in light of the accident in December 2010 and in previous accidents?

Which measures that you have undertaken do you think will be the most effective?

How are you going to measure improvement?

3. Regulations

What regulations govern lab safety at NU and other universities in Illinois?

Would it be helpful to have regulations that would require enforceable policies?

How could regulations be changed to mandate safe practices in university laboratories?

Are you familiar with the OSHA Laboratory Standard? Does it play a role in lab safety at NU?

4. Elements of safety culture –

What do you think safety culture means for NU?

Which are easy to address?

Which are difficult?

List of possible elements:

Accountability and oversight

Chemical Procurement and Inventory

Safety Committees

External Peer Review

Chemical Hygiene Plans -

Inventory/identification of Hazardous Labs –

Chemical Inventory

Procedures for opening and closing labs

5. The Integrated Safety Information System (ISIS) program

Please describe and demonstrate the ISIS program.

How has the program helped improve Safety Culture at NU?

Have the roles of PI, Provost, and EHS staff changed?

Questions for a NU Chemistry Professor:

What are the main safety issues that need to be corrected at NU?

Do you know what safety culture is? Is safety culture improving at NU?

Do you think that the actions of the working group on laboratory safety will make a difference in safety culture at NU?

In your opinion has there been any change in the accountability for PI's or other parties for lab safety?

Has it been made more clear who has responsibility?

Has oversight of laboratories of improved since the accident?

What part of the procedures or the improvements in safety and health policy you see that will make a long-lasting difference?

Questions for an NU student:

How long have you been a student at NU?

Has the lab been inspected lately? Was the lab cited for violations? Anything serious?

Have you been trained what to do in case of fire in the lab?

Have you been trained how to use pyrophoric materials?

Have anyone been trained for fire preparedness?

Who is responsible for laboratory safety?

Where would you go if you had a question about a procedure that you were asked to do?

Do you think your lab is safer than others?

Do you think there is a safety culture in your department?

Do you know who the EHS staffer assigned to your lab is?

Is there a safety committee in your department?

QUESTIONS FOR DARTMOPUTH PARTICIPANTS

Introduction/Background

The goal of these questions is to find out what has gone on since the accident in 1997 to change/improve laboratory safety at Dartmouth and how effective the measures are at addressing laboratory safety practice.

Questions for the EHS Director at Dartmouth:

Background of the participant

Where does EHS fit in to the administrative structure of the university?

Root Causes of Problem

What do you think the main safety issue was that needed correction in light of the accident in 1997?

How has the understanding of the toxicity of dimethylmercury changed because of Karen Wetterhahn?

What modifications to safety practice have been instituted at Dartmouth since Karen Wetterhahn's death?

Which measures that you have undertaken do you think will be the most effective?

How is that measured?

Regulations

Are there State regulations (State?, Local?) that govern lab safety at Dartmouth?

How could regulations be changed to mandate safe practices in university laboratories?

What role does the OSHA Laboratory Standard play in lab safety at Dartmouth?

Safety Committees

Are there safety committees?

How much representation is there of rank and file students, graduate students and laboratory staff in these committees?

How do the committees get involved in health and safety at Dartmouth?

Questions for a chemistry professor:

What are the main safety issues that need to be corrected at DARTMOUTH?

Do you know what safety culture is? Is safety culture improving at DARTMOUTH?

Do you think that the actions of the working group on laboratory safety will make a difference in safety culture at DARTMOUTH?

In your opinion, has there been any change in the accountability for PI's or other parties for lab safety?

Has it been made more clear who has responsibility for laboratory safety?

Has oversight of laboratories of improved since the Working Group Report?

What part of the procedures or the improvements in safety and health policy you see that will make a long-lasting difference?

Has the roll of EHS changed?

Has the perception of EHS changed?

Questions for rank-and-file staff persons:

In your opinion, what are the problems in safety at Dartmouth?

Do you know what safety culture is? Is safety culture improving at Dartmouth?

Do you think that the actions of the safety committee or the recommendations of the safety committee are being taken seriously and will in fact make a difference in safety culture at Dartmouth?

In your opinion has there been any change in the accountability for PI's or anybody for safety?

Has it been made more clear who has responsibility?

Has oversight of laboratories of improved since this accident?

Does anything in the procedures or the improvements in safety and health policy you see that will make a long-lasting difference?

Questions for a student:

How long have you been a student at Dartmouth?

Has the lab been inspected lately? Was the lab cited for violations? Anything serious?

Have you been trained what to do in case of fire in the lab?

Have you been trained how to use pyrophoric materials?

Have anyone been trained for fire preparedness?

Who is responsible for laboratory safety?

Where would you go if you had a question about a procedure that you were asked to do?

Do you think your lab is safer than others?

Do you think there is a safety culture in your department?

Do you know who the EHS staffer assigned to your lab is?

Is there a safety committee in your department?

QUESTIONS FOR UCLA PARTICIPANTS

Introduction/Background

The goal of these questions is to find out what has gone on since the accident in December 2008 to improve laboratory safety at UCLA and how effective the measures are at addressing laboratory safety practice.

Questions for the EHS Director at UCLA:

1. Background of the participant

2. Root Causes of Problem

What do you think were the main safety problems that needed correction in light of the accident in December 2008?

Which measures that you have undertaken do you think will be the most effective?

How are you going to measure improvement?

3. Regulations

What regulations govern lab safety at UCLA and state-funded universities in California?

How could regulations be changed to mandate safe practices in university laboratories?

Are you familiar with the OSHA Laboratory Standard? Does it play a role in lab safety at UCLA?

4. Safety Committees

How much representation was there of rank and file students, graduate students and laboratory staff?

How would you characterize the recommendations of the committee?

How are you addressing the recommendations of the committee?

Are there departmental safety committees?

5. Safety Committee recommendations

A. Which elements are the easiest to address?

B. Which are the most difficult?

6. Laboratory Assessment Tool

Describe the laboratory hazard assessment tool

How much participation is there in implementing it?

How will it help EHS and improve safety?

Questions for Cal/OSHA person:

What are the main issues that need to be corrected at UCLA?

Have they been corrected to Cal/OSHA's satisfaction or is improvement still underway?

3. Is the jurisdiction of Cal/OSHA in California universities similar to OSHA's jurisdiction? Is it more or less? Does the fact that it is a public university make a difference?

3. How many times since the accident has Cal/OSHA inspected UCLA laboratories?

4. Is there a record of inspections and citations prior to the accident?

Will this make improvements in safety at UCLA?

5. Does Cal/OSHA have a different but similar document to the OSHA Lab Standard?

6. How do you think accountability could be improved?

7. One of the recommendations of the safety committee was improve laboratory design. Do you have an opinion about how the layout or configuration of labs contributes to safety?

8. What were Cal/OSHA's issues with the Chemical Safety Officer?

Questions for a chemistry professor:

What are the main safety issues that need to be corrected at UCLA?

Do you know what safety culture is? Is safety culture improving at UCLA?

Do you think that the actions of the working group on laboratory safety will make a difference in safety culture at UCLA?

In your opinion, has there been any change in the accountability for PI's or other parties for lab safety?

Has it been made more clear who has responsibility for laboratory safety?

Has oversight of laboratories of improved since the Working Group Report?

What part of the procedures or the improvements in safety and health policy you see that will make a long-lasting difference?

Has the roll of EHS changed?

Has the perception of EHS changed?

Questions for rank-and-file staff persons:

In your opinion, what are the problems in safety at UCLA?

Do you know what safety culture is? Is safety culture improving at UCLA?

Do you think that the actions of the safety committee or the recommendations of the safety committee are being taken seriously and will in fact make a difference in safety culture at UCLA?

In your opinion has there been any change in the accountability for PI's or anybody for safety?

Has it been made more clear who has responsibility?

Has oversight of laboratories of improved since this accident?

Does anything in the procedures or the improvements in safety and health policy you see that will make a long-lasting difference?

Questions for a student:

How long have you been a student at UCLA?

Has the lab been inspected lately? Was the lab cited for violations? Anything serious?

Have you been trained what to do in case of fire in the lab?

Have you been trained how to use pyrophoric materials?

Have anyone been trained for fire preparedness?

Who is responsible for laboratory safety?

Where would you go if you had a question about a procedure that you were asked to do?

Do you think your lab is safer than others?

Do you think there is a safety culture in your department?

Do you know who the EHS staffer assigned to your lab is?

Is there a safety committee in your department?

APPENDIX D

CHAPTER III - STAKEHOLDERS INTERVIEWED

This appendix presents information about the interviews conducted as part of the research for this paper.

UCLA

In March 2011, Interviews were conducted with stakeholders in Los Angeles at UCLA and with a Cal/OSHA representative. The following people were interviewed regarding the accident at UCLA and subsequent changes to health and safety practice. Most of the UCLA interviews took place on March 15 and 16, 2011. Materials were sent by a member of the International Union of IUPTE from their safety newsletter which discussed the accident and Cal/OSHA's investigation. The list of UCLA interviewees is presented in Table D-1.

Table D-1

UCLA Interviews

Stakeholder	Place of Employment	Job Title
Judy Sweeney	UCLA Chemistry	Administrative Specialist
Rita Kern	UCLA Medical School	Staff research associate-member IUPTE
Dr. James Gibson	UCLA EHS	Director UCLA EHS
Deborah Gold	Cal/OSHA	Senior Safety Engineer

Dr. Albert Courey	UCLA Chemistry	Chair UCLA Chemistry
Dr. Melissa Prado	UCLA EHS	Laboratory Safety Officer
Undergraduate Students	UCLA	Science students

Informal interviews also took place with a biology student, and a biology lab manager. A review of a presentation given by Dr. Gibson at the American Chemical Society's (ACS) Meeting on UCLA's actions after the accident was also reviewed. Northwestern

Northwestern

In April 2011, Interviews were conducted with Office of Research Safety (ORS) Staff at NU in Evanston, Illinois. Interviews were conducted with L. Todd Leasia and two of his staff. Dr. Theresa Collins was also interviewed. Dr. Collins, at the time, was the instructor in charge of the safety committee. At a later visit, in June 2011, an interview was carried out with a chemistry graduate student. In October 2011, a phone interview took place with a chemistry professor. Additional information was collected via email from several science students. The list of NU interviewees is provided in Table D-2.

Table D-2

NU Interviews

Stakeholder	Place of Employment	Job Title
L. Todd Leasia	NU ORS	Director EHS
Markus Schuefele	NU ORS	Chemical Hygiene Officer
Nicholas Waddell	NU ORS	Lab Safety Specialist
Dr. Theresa Collins	NU Chemistry	Safety Instructor
Martin Donakowski	NU Chemistry	Doctoral Student

Dr. Joseph Hupp	NU Chemistry	Professor of Chemistry
Clement Stokes	NU	Director for Emergency Management
Three students and former students	NU	

Dartmouth

Since the accident at Dartmouth occurred almost fifteen years ago, the people available to talk about it were limited. The interview with Dr. Michael Blayney, the Director of EHS at Dartmouth took place on July 6, 2011. Later, the Chemical Safety Board created a video in which one of the chemistry faculty members, John Winn, who was a colleague of Dr. Karen Wetterhahn was interviewed. Information from the video was used to supplement Dartmouth case. Additional information was obtained from two recently graduated undergraduate science students. Dr. Blayney provided a list of articles that he had collected, some of which he had authored or co-authored following the accident. Table D-3 presents the stakeholders interviewed at Dartmouth.

Table D-3

Dartmouth Interviews

Stakeholder	**Place of Employment**	**Title**
Dr. Michael Blayney	Dartmouth EHS	Director
Dr. John Winn	Chemistry Department	Professor
Three former undergraduate students	Dartmouth College	Graduates of Dartmouth

BIOGRAPHICAL SKETCH OF THE AUTHOR

Miriam Weil spent over 20 years as a risk assessor in private consulting, performing human health and environmental risk assessments for hazardous waste sites throughout New England and other locations in the United States. These assessments required extensive use of chemical exposure and toxicity information which led to a lifelong commitment to reduce chemical exposures and chemical wastes through improved chemical management. This was facilitated by her undertaking of the doctoral program in work environment policy, specifically focusing on chemical information management.

Her specific interest in chemical management and health and safety arose from her experience working at Harvard University's Office of Environmental Health and Safety. While there she trained students how to keep track of the chemicals they were using and helped organize and implement a search and chemical inventory system for the university. This experience sparked an interest in the cultural aspects of academic laboratory operations and formed an underlying theme for her dissertation.

Miriam Weil holds Bachelors Masters Degrees in Geography from University of California Los Angeles (UCLA), a Master's Degree in Public (Environmental) Health from Boston University School of Public Health.