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Process Safety Management: Optimized Models Influenced by Organization Culture

Taehoon Lee

Process Safety Management:

Optimized Models Influenced by Organization Culture

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Taehoon Lee

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ABSTRACT

Lee, Taehoon

EMGT

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Process Safety Management: Optimized Models Influenced by Organization Culture

Project Advisor: Dr. Craig Downing

Companies focus on Process Safety Management (PSM) in order to protect employees and facilities from an accidents, such as explosion and fire. The most elements of PSM are closely related to employees, which determine the organizational culture, and organizational culture directly affects safety culture. Companies put an effort to have a strong safety culture, which is behaviors and responses in regard to emergency and abnormal situation. In this paper, definition and essential theories of PSM were reviewed first, and safety culture in PSM and the safety culture of Indianapolis Power & Light (IPL) were discussed. A method used in IPL was to conduct the safety survey to evaluate their safety culture. To understand the safety culture in Rose-Hulman Institute of Technology (RHIT), two similar safety surveys were performed. The first survey was to understand students' perceptions about Personal Protective Equipment (PPE) in the laboratory, and the second survey was to study what type of methods are used for the safety training in companies and find current safety problems and solutions of the Chemical Engineering Unit Operations laboratory. Based on the results of the surveys, the safety culture of RHIT was analyzed and possible solutions were suggested.

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LIST OF ABBREBIATIONS

PSM	Process Safety Management
OSHA	Occupational Safety and Health Administration
EPA	Environmental Protection Agency
CCPS	Center for Chemical Process Safety
ChE UO Lab	Chemical Engineering Unit Operations Laboratory
HAZOP	Hazard and Operability Study
FMEA	Failure Mode Effects Analysis
CMA	Chemical Manufacturers Association
API	American Petroleum Institute
RBPS	Risk-based Safety Management
BRF	Basic Risk Factor
PDCA	Plan-Do-Check-Act
SOP	Standard Operating Procedure
IPL	Indianapolis Power & Light
EHS	Environment, Health & Safety
SCBA	Self-contained Breathing Apparatus
NSC	National Safety Council
RHIT	Rose-Hulman Institute of Technology
PPE	Personal Protective Equipment
SDS	Safety Data Sheet
AIChE	American Institute of Chemical Engineers
HIRA	Hazard identification and risk analysis
MOC	Management of Change

1. INTRODUCTION

As new technologies are developed, industry processes become more complicated. The processes are required to involve lots of factors, which were not used before, in order to produce perfect products. As a result, people receive the benefits from high quality with low price of products, and companies also flourish their business and invest more capital to develop their technologies to make better products with low costs. However, these changes, ranging from simple to complicated, are accompanied by risks of process failure as well. The risks not only affect their business but also can be connected with the safety of the workers and the general public.

In the pharmaceutical and oil industries, handle hazard chemical materials the most, a single small failure in Process Safety Management (PSM) can bring about extreme damages and casualties. Due to this high risk followed by failure in process, the process management becomes important to secure safety and must be precise and delicate. For this reason, chemical companies have been concentrated on PSM to reduce accidents in the workplaces, and Occupational Safety and Health Administration (OSHA), Environmental Protection Agency (EPA), Center for Chemical Process Safety (CCPS) issued PSM guidelines to reduce risks and prevent accidents before it happens. Even though those guidelines were provided to companies, diverse accidents occurred by failures of process management in last few years, which could have been prevented and minimized the damages by PSM. For example, the West Fertilizer Company explosion in 2013 resulted in 15 fatalities, more than 260 injuries, and widespread community damage [1]. Incidents from the failure of PSM reminded people of its importance and made people reconsider the causes of failure of PSM. To understand why the accidents keep occurring, it is important to know what the references cover. The references published by organizations commonly mention about probable

hazard factors, operating procedures, emergency planning, incident investigations, employee training and participation. Even though all the technology and equipment are managed as the references by companies, it is difficult to fully assure that employees are following the regulation. Based on the conditions of PSM, the results of the process would be different due to human forces. It is because individuals have different perspective and knowledge in equipment, processes, environment, and safety. In addition, the perspective and knowledge of employees are also different from company to company. The frequency of PSM training for employees and the evaluation of PSM are performed in the company could be essential factors to affect overall PSM. In other words, having appropriate safety culture in organizations is an essential key to reduce accidents and prevent catastrophes.

As previously mentioned, a few organizations have issued guidelines that help to prepare and prevent unpredictable accidents causing enormous casualties and damages on companies. Even though the guidelines are from different organizations, the contexts of references have similarities for successful PSM. Since the references are designed and used for the chemical industry, it is difficult to apply all the principles are included in university laboratories. However, there are some factors related employees and organizational culture which could be used and improve the safety environment. The university laboratories are less dangerous and smaller sizes compared to actual chemical companies, but its processes and chemicals used for experiments are still harmful to faculties, staffs, and students.

For this study, the common theoretical background of PSM and essential concept will be reviewed. Furthermore, how companies utilize those PSM elements will be discussed. Last, but not least, current status and the direction of improvement for the Chemical Engineering Unit Operation Lab

(ChE UO Lab) will be discussed based on collected data, and the results of the analysis will help utilize into broader applications in the future.

2. DEFINITION OF PROCESS SAFETY MANAGEMENT

Initially, industries concerned about the process safety evaluated their process based on experiences and expertise of people. Since these uncertain methods could not guarantee the safety, industries started to adopt and utilize the formal review techniques for accessing process safety, such as Hazard and Operability Study (HAZOP), Failure Mode Effects Analysis (FMEA), Checklist, Fault Tree Analysis, and What-If reviews [2].

2.1 History

PSM was not firmly rooted in the U.S chemical industry before two chemical accidents occurred in Seveso, Italy in 1976, and Bhopal, India in 1984. Even though the accidents, which damaged residential areas and resulted in more than 3,000 casualties, were occurred abroad, the accidents were enough to acknowledge the importance of PSM to U.S. chemical industries [2]. After the accidents, the CCPS was established to eliminate the risks in the process industries. Other organizations such as OSHA and EPA started to take an active interest in process safety, and useful guidelines were issued for improving process safety.

In the 1990s, the Chemical Manufacturers Association (CMA), the American Petroleum Institute (API), and OSHA issued PSM guidelines, which are widely utilized by companies [2]. The safety organizations performed diverse case studies on small and big accidents and opened the reports to the public so companies could prevent and prepare for similar accidents in the future. Important elements and essential steps developed and derived from case studies have been added to previous guidelines. Safety practices has been taught to engineering students before they start in professional industries.

2.2 Definition of Process Safety Management (PSM)

PSM is a management system that focuses on prevention, preparation, mitigation, and restoration of accidents from a chemical or energy process. Utilization of PSM detects flaws of processes, evaluates facilities and employees, improves process safety of facilities by removing the risks and protecting workers, facilities, and the public from invisible dangers. OSHA PSM and CCPS' Risk-based Safety Management (RBPS) are the most credible references among guidelines from institutes and organizations in process industries.

Table 1. Comparison of essential elements from OSHA and CCPS's PSM guidelines [2]

	CCPS RBPS	OSHA PSM
Commit to Process Safety	Process Safety Culture	
	Compliance with Standards	Process Safety Information
	Process Safety Competency	
	Workforce Involvement	Employee Participation
	Stakeholder Outreach	
Understand Hazards and Risk	Process Knowledge Management	Process Safety Information
	Hazard Identification and Risk Analysis	Process Hazard Analysis
Manage Risk	Operating Procedures	Operating Procedures
	Safe Work Practices	Operating Procedures Hot Work Permits
	Asset Integrity and Reliability	Mechanical Integrity
	Contractor Management	Contractors
	Training and Performance Assurance	Training
	Management of Change	Management of Change
	Operational Readiness	Pre-Startup Safety Review
	Conduct of Operation	
	Emergency Management	Emergency Planning and Response
Learn From Experience	Incident Investigation	Incident Investigation
	Measurement and Metrics	
	Auditing	Compliance
	Management Review and Continuous Improvement	

As shown in Table 1, OSHA PSM and RBPS determined 14 and 20 elements for successful PSM, respectively, and many elements and contexts are overwrapped one another because the ultimate

goal of the two guidelines are identical to create a safe work environment. Since the CCPS RBPS covered elements that OSHA PSM did not cover, this section would be categorized based on the CCPS RBP's elements, but the context would cover both PSM guidelines.

It is important to define risks in the process industries before discussing PSM elements. A typical dictionary definition of risk is the possibility of damage or loss. In the process industries, it could be casualties and destruction of facilities. According to the CCPS definition, risk has three factors: the hazard, the magnitude, and the likelihood [3]. The hazard represents the factors that would be damaged by accidents, such as human injury and environmental damage. The magnitude represents how serious the damages are. It could be determined as the number of people injured or the amount of loss in economy. The likelihood represents how frequent the accident might happen. For example, the accident could occur once in a month or twice in a year. Based on three factors, the risk in the process is determined. The risk differs depending on materials used in the process, conditions of equipment and facilities, the complexity of the process, and the like. However, no matter how serious the risks are, companies must make sure that the risks are removed or minimized to reduce the damages when the risks turn into disasters.

To focus on cultural aspects of PSM, this paper will not cover all the details of each category. However, concepts related to organizational culture are briefly explained in Appendix A.

2.3 Description of Essential Theories

Previously mentioned, since the Seveso and Bhopal explosions, PSM has been highlighted in the United States. Researchers and engineer tried to secure safety of process, and during the period diverse theories related in PSM was derived. Due to the theories, organizations and employees could understand PSM better and protect their environment from risks.

2.3.1 Swiss Cheese Model

The Swiss cheese model is the most common approach to analyze the process safety [4]. To secure the safety of facility, equipment, and process, several steps of safety devices function and each device protects the process and eliminates possible hazards that could result in accidents. As shown in the Figure 1, each slice of cheese represent the safety devices, such as pressure safety valves, pressure relief valves, and alarms. Holes in the slice symbolize the deficiency or limitations due to specifications, design, or conditions.

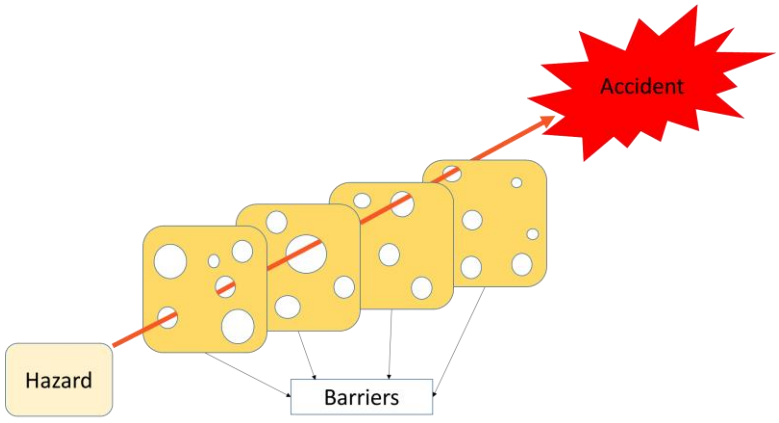


Figure 1. Scheme of Swiss cheese model [4]

For example, a fire shutter stops fire spread to other areas. It should have a certain resistance to endure high temperature, but it may be broken by high pressure. Several fire shutters would be useless unless there is a method to resolve the high pressure. In certain scenarios, when holes of cheese slices are aligned, then a toothpick easily get to the end without any trouble; however,

putting another slice from a different part of cheese would stop that the toothpick all the way through. The main point of the Swiss Cheese Model is to show that a single hazard can become an accident when the hazard passes through the deficiency of all the devices. To prevent accidents, the process might need diverse equipment or systems with fewer defectives that could stop the hazards immediately.

2.3.2 Tripod Theory

Tripod Theory, developed at Leiden and Manchester University, was initially for investigating ways to reduce human error in the Dutch Royal/Shell Group in 1986. The primary focus of the Tripod Theory is to control the working environment to prevent human error. The theory focuses on making an equilibrium between substandard acts and compensating factors, illustrated in Figure 2, to avoid operational disturbances [5].

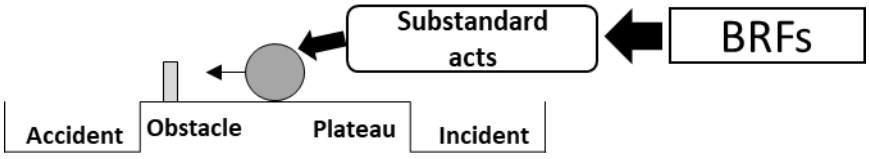


Figure 2. Illustration of tripod theory with a marble and plateau [5]

The marble is moveable to either right or left side, and the factors that move marble are human error, called the 'latent failure'. The latent failure exists in the system, but it does not occur without a specific trigger, called the Basic Risk Factors (BRFs). However, when a factor triggers a potential hazard, it dramatically results in a critical accident. As shown in Table 2, the prevention BRFs focus on prevention of accident, while a mitigation BRF focuses on management of consequences of the accident.

Table 2. The Basic Risk Factors in Tripod Theory [5]

10 Prevention BRFs - Design: ergonomically poor design of tools of equipment - Hardware: poor quality, condition, suitability or availability of materials, tools and equipment - Maintenance: no or inadequate performance of maintenance tasks and repairs, bad planning - Housekeeping: no or insufficient attention given to keeping the work floor clean and tidied up - Error Enforcing Conditions: unsuitable physical conditions (cold, heat, noise, darkness, etc) or personal factors (motivation, boredom, stress, complacency, etc) influencing human functioning - Procedures: insufficient quality or availability of procedures, manuals and written instructions - Training: inadequate planning, ineffectiveness of trainings, insufficient competence or experience of personnel - Communication: ineffective communication between sites, departments, individuals - Incompatible Goals: unsuitable situations in which people must choose between optimal working methods on one hand and the pursuit of production, financial, social or individual goals on the other one - Organization: shortcomings in the organizational structure, organization's philosophy, management strategies
1 Mitigation BRF - Defences: insufficient protection of people, material and environment against the consequences of operational disturbance

In Figure 2, the plateau represents how resilient the organization is and gives small resistance to the marble. The resilience of organization means how quick an organization can recover from recent incident or accident and prepare to avoid similar or same situations. It differs from company to company.

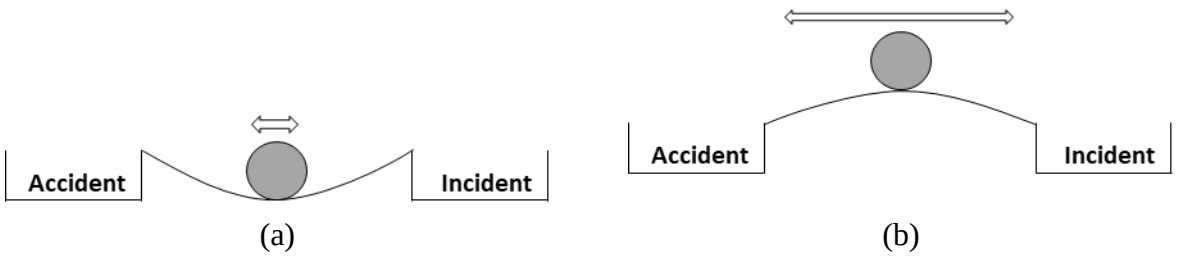


Figure 3. Illustrations of (a) Resilient organizations and (b)Non-resilient organizations [5]

Depending on the resiliency of companies, the angle and direction of the plateau' curvature are different, as shown in Figure 3. The marble of a resilient company is less likely to move from center to other sides as shown in Figure 3a, while the marble of non-resilient company is easily

moved to other sides by BRF as shown in Figure 3b. To prevent or avoid accidents, companies may put obstacles on the plateau, but the obstacles do not always work.

2.3.3 Plan-Do-Check-Act (PDCA)

PDCA, a general method to change, improve, and manage a system, could be utilized in PSM. This method is usually used in improving quality and system, but this method is able to implemented and used for process safety. To improve the safety of an organization, it is important to acknowledge the current safety status and plan to develop and amend the system, if necessary. Planning is the first step and must be performed before any other steps. Planning requires the commitment of top management to manage the overall organizations efficiently. Based on the safety information organization has, employees and management teams need to consider how they could improve the environment in safety perspective. Also, all individuals' roles and responsibilities should be clearly communicated. "Do" is the step to execute the "Plan". The execution phase has to guarantee that all the changes and plans are adequately performed and the data from changes are collected for analysis. In this step, all individuals must know their roles and perform their responsibilities. In "Check" stage, the collected data needs to be analyzed to determine problems from changes and learn from those problems. Some changes may or may not effective on the organization. Follow step is "Act", which is analyzed the collected data and find a new different way to improve the process. "Act" step could show a different direction of changes in the future. The organization should not stop improving and monitoring their process. They have to keep their eyes on the changes and system, and if it needs additional actions to solve problems, then they should start from "Plan" step to resolve the situation.

3. Process Safety Culture

The Bureau of Labor Statistics (BLS) claims that 5,190 fatal work injuries were recorded in 2016, which is an increase of 7% in fatal work injuries in 2015 [7]. Although many companies attempt to improve safety, the number of fatal work injuries seems unlikely to decrease easily. There are many factors related to fatal industrial work injuries. Specifically, one factor includes the lack of process safety culture in companies.

3.1 Process Safety Culture

To begin it is necessary to define what a safety culture is. An article, Assessing Safety Culture, defines culture as being "comprised of norms or patterns of perceptions, speech, and even building design features that make the culture what it is" [8]. In other words, a culture is not made by simply one feature. Various features of processes and companies are involved and correlated. These complicated relations between features form an organization's culture.

CCPS defines process safety culture as "the combination of group values and behaviors that determine the manner in which process safety is managed [9]." Safety culture is how employees feel, react, and respond to their work and environment. For example, when two employees find the same small defect in the equipment and fix it, one employee may not notify a defect of equipment because it was negligible, while another employee may share what he or she saw and did for the problem and ask colleagues for their opinion about the defect. Even though it was a small defect, those two employees' behavior and response were completely different. For a company with large facilities, sharing opinion and action for small problems in the process might be unnecessary. However, an organization with employees who are sensitive to process safety and the environment are more likely to be safe and have a better environment to work.

It has not been long since companies began to recognize the importance of safety culture. One of the examples of failure of adequate safety culture is the Chernobyl accident in 1986 [10]. During the Cold War, Soviet Union focused on overall production rate over safety. Since it was the beginning of the nuclear industry, people did not acknowledge or understand the danger of radiation. Due to this, the operators tended to violate the safety rules and Standard Operating Procedures (SOPs). In addition, even though other companies found malfunctions in the same processes in their facilities, they did not fix and review those problems before operating the processes. Eventually, the neglect and ignorance in safety resulted in one of the most damaging accidents in the world. After the Chernobyl accident, companies and employees have taken an interest in safety culture and studied to define what good safety culture is in order to avoid catastrophe [10].

3.2 Importance of Process Safety Culture

An easy way to understand the safety culture of an organization is to see the vision and the ultimate goal of the organization, which often reflect overall company [8]. The vision and goals of the company affect who they hire, how they train employees, their values, etc. Companies and entrepreneurs initially start their businesses with a vision and goals. In order to run the business in line with the vision and achieve their goals, they need employees who agree with their vision and have a similar way of thinking. By gathering those individuals, the business' unique cultures are formed. However, organizations must ensure that their vision and goals create positive impacts for the business and public. Actually, in Alcoa, one of aluminum manufactures, after Paul O'Neil, who considers safety is the utmost factor, became a new CEO in 1987, the accidents rate in the plant significantly was reduced from 320 cases to 18 cases per year within in 5 years [6].

Assume there are Company MONEY and Company SAFETY, ethanol production companies. Company MONEY puts its profit before safety, employees, and the environment. They hire ordinary engineers and operators with low salaries to optimize their profits. Rather than focusing on the safety of the facility, employees, and following federal regulations, the culture was more focused on increasing production rate and profits. Sooner or later, Company MONEY will face severe issues in regards to safety, employees, and the environment. Employees might be injured or killed from accidents resulting from malfunction of equipment, or the company may pay a huge amount of fines due to violations of EPA regulations. In contrast, Company SAFETY considers safety, employees, and the environment as more important factors than profits. For process safety, they hire excellent engineers and experienced operators. They conduct a safety meeting every day. Company SAFETY may struggle with lower profit, but they will not have the problems that Company MONEY went through.

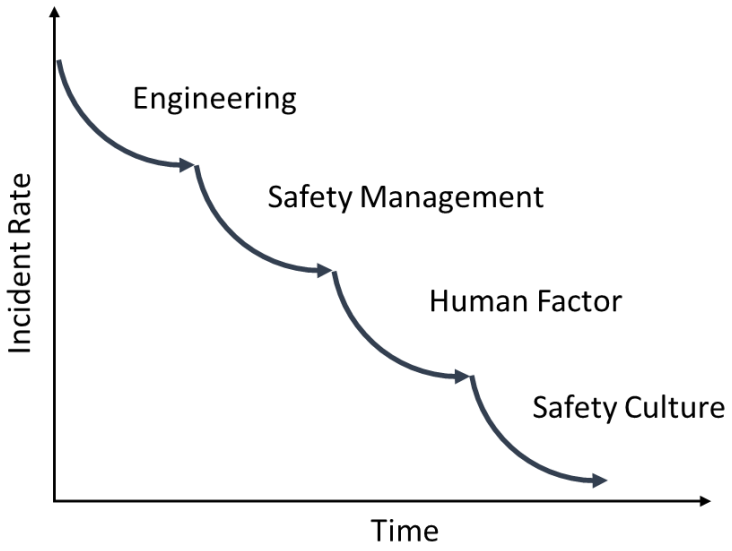


Figure 4. Historical industry attention in order to reduce incident rate [11]

Figure 4 shows historical priority related to elimination of industrial risk and reduce the accident rate. Four elements including engineering, safety management, human factor, and safety culture,

contribute to reducing the accident rate to a certain extent. In the past, people were more focused on technology and management of equipment. Setting up safety devices and using new technology could reduce risks of an extent; however, people were underestimate errors caused by human being. As time goes, the focus moved toward human factor, and now safety culture is considered very important in reducing incident rate one more step. If organizations with engineering, safety, and human factor, does not have a strong safety culture, the incident rate would not go down anymore [11].

Building a strong safety culture requires not only individuals' efforts, but also systematic supports from the organization. As shown in Figure 5, there are six elements that influence on safety culture: individual awareness, knowledge and competence, commitment, motivation, supervision, and responsibility [12]. Employees and organization with strong culture have all six elements.

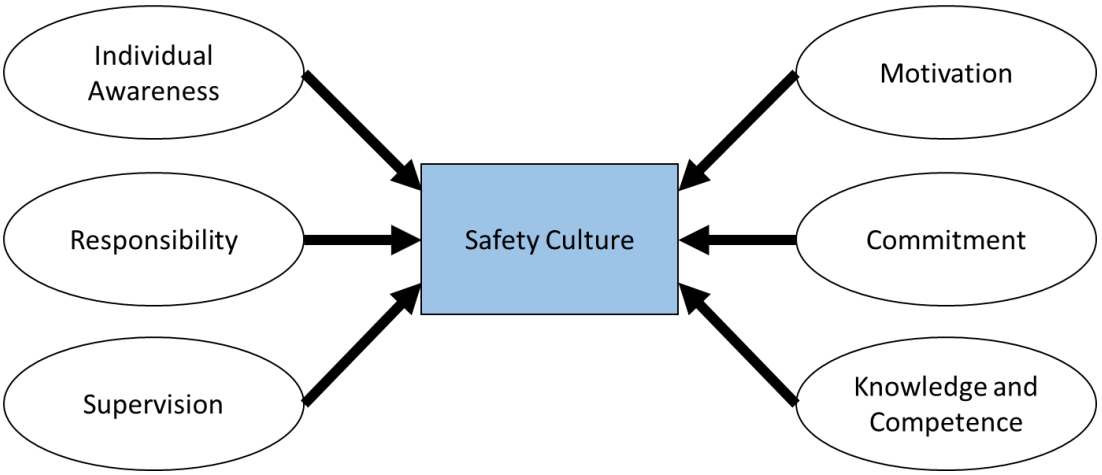


Figure 5. Six essential elements to build a strong safety culture [12]

It is important to know individuals' responsibility. By thoroughly understanding description of duty and given assignments/project, employees quickly react and respond to changes because they know consequences of failure in their given duty. In performing tasks, individuals should be aware

of the importance of safety as well. The awareness of safety may come from different sources, such as seminar, school, meetings, or experiences. Even though they are from different sources, it is important that employees perceive and consider safety first before other factors.

Also, employees should have a certain level of knowledge in processes and safety in order to respond emergency or unusual circumstances. The worst situation is that an employee notices a problem in the process but does not perceive its risks, consequences, and what to do about it. If employees do not have the fundamental and professional knowledge, organizations must provide safety seminars and classes to educate their employees in order to increase the level of knowledge in safety.

Performing audits and evaluating employees also strengthens a safety culture. Audits make an organization recognize current safety problems. Employees need to prepare for audits and evaluation and may rethink their duties, responsibility, and safety. Also, companies may choose trained employees as auditors and send them to other facilities for audits in order to learn the differences between facilities. In this way, the employees might objectively evaluate the organization.

In order to make a strong safety culture, the company needs to motivate employees to voluntarily improve the safety of company. The company may run systems of rewards and sanctions and create slogan/posters to remind employee of the importance safety. In addition, all these activities and changes mentioned previously build a strong safety culture and should be committed by a top level management and employees should understand and follow the changes.

3.3 Example of Process Safety Culture

Nowadays, companies emphasize safety because not only has the fatal work injury rate been increasing, but also accidents with casualties bring enormous damages to companies. The author of this paper had a chance to work at Indianapolis Power & Light (IPL), one of the global energy suppliers, and would like to share what he has done for process safety and safety culture.

3.3.1 Indianapolis Power & Light

IPL is a part of the AES company, which runs two power plants to supply electricity to Indianapolis. One of the facilities is located in Petersburg, Indiana, where over 70% of total electricity for Indianapolis is produced. Due to coal, which is the main resource, there were various threats which could injure or kill employees and others in and around the facility, such as an explosion, fire, suffocation by CO and CO_2, electric shocks, and others. EHS (Environment, Health, & Safety) in IPL, fortunately, recognized the dangers and tried to make people feel safe in their workplace. In addition, since contractors were doing the majority of maintenance, they needed to train contractors to take care of their safety as well.

3.3.2 Major Roles and Responsibilities of EHS

EHS team in IPL has responsibility for human safety and safety culture in the plant. Their duty was to perform safety training for IPL's and contractors' employees, manage work permits, inspect the facility, supervise ongoing process in terms of safety, and other tasks related to human safety in the plant. Before employees started to operate equipment after maintenance, it was mandatory that the EHS inspect the site in order to make sure that there are no risk factors. Additionally, if the EHS found risks at the site while the process is running, they have the authority to stop the process immediately in order to avoid accidents. When someone was injured in the plant, they reviewed the situation, the risk factors, and solutions to avoid a similar accidents and then sent out

an email to all employees in order to raise awareness of safety. In addition, once in a month, EHS hosted a safety meeting and discussed detected problems and improvements of the safety of the facility with leaders and managers of departments. Also, they managed equipment used for emergency and safety devices, such as SCBA (Self-contained Breathing Apparatus), harnesses, and oxygen monitors.

3.3.3 Internal and External Audits

AES regularly performs internal and external audits for all US facilities to evaluate process safety and safety culture. External audits are completed once every three years. Employees who have been trained at other AES facilities will evaluate IPL facilities. The audit process typically lasts three to five days. On the other hands, internal audits take place twice per year. Each internal audits use different programs and policies in order to cover the diverse regulations. IPL tries to review each program and policy with a three-year timeframe. Prior to internal and external audits, employees are notified that an audit is forthcoming.

Recently, National Safety Council (NSC), visited IPL plant in June 2017 to evaluate the safety culture of IPL. NSC was commissioned by AES to evaluate all US AES facilities. NSC interviewed all management team, leaders, engineers, and hourly workers in order to understand their behaviors and responses in certain circumstances.

In February 2017, the safety perception survey was performed as well and was analyzed by DuPont, which is a company has a great process safety management system. All managers, supervisors, hourly workers, professionals performed the survey. The questions were about the employees' behavior and safety system of IPL. As shown in Figure 6, all the responses were analyzed and sent back to the safety team in order to improve and resolve found problems by acknowledging current

standing. The survey report from DuPont is found in Appendix B. Since the survey was performed for all AES facilities, it was able to compare the safety perception of IPL with others.

Figure 6. Example of survey analysis performed by DuPont for IPL facility

Administering the survey and interviews with employees and manager about the safety of facility not only made employees think about safety one more time, but also allowed EHS to detect current problems and can provide insight on how to resolve the problems.

3.3.4 Process Safety Management

In compliance with OSHA's regulations, chemical processes must be managed for the safety of the plant. In order to do that, two employees in EHS were professionally trained in 2016 to manage

the PSM of the site. At the end of 2016, EHS of IPL requested SaftEng, process safety consulting company, to determine their current status of PSM and resolve any problems in the current anhydrous ammonia process, which is considered the most hazardous process in the plant. Based on OSHA's guideline, the process was carefully reviewed. Some elements did not meet with current OSHA's rules. The company started to develop solution to the problems highlighted in the PSM audit.

3.3.5 Safety Day

IPL takes care of employees not only at work, but also off the job. All employees in AES are precious for the company because the company is run by employees. That is, their safety directly affects the company's business. It is important to manage their safety and lives when they are not on duty. IPL holds the 'Safety day' every year to teach how to keep away from hidden risks outside of the plant. Employees learn how to use common power tools and are provided safety speeches from professional safety instructors.

4. Application of Process Safety Management into RHIT

The process safety management was initially designed for chemical, pharmaceutical, and other industries. Following OSHA PSM and CCPS RBPS does not guarantee that a company will not have any accidents, but they are able to prepare for unexpected accidents and reduce damages when accidents occurs. No matter the damage of accidents, companies must prepare for them and always try to improve their safety.

University laboratories are not dramatically different from companies. They use various equipment and chemicals as other companies do, and students and faculty are also exposed to accidents. The only difference between industry and university laboratories is the extent of damages when it occurs. Since university laboratories are mainly used for education, they do not handle seriously hazardous chemicals and equipment as some companies. However, there is a possibility of an accident and explosion, which have to be managed. The accidents may occur from malfunction of equipment or process in university laboratories, but culture of university laboratories is another important factor to be considered.

4.1 Background

RHIT (Rose-Hulman Institute of Technology) has more than 2,200 students and many different kinds of laboratories in order to educate students with different majors, such as laboratories for chemical engineering, mechanical engineering, electrical engineering, chemistry, biochemistry, and optical engineering. Fortunately, the school has not had severe accidents in past few years; however, no one knows when it will happen. From the experience from IPL, performing survey gives some idea of current status and safety culture of organization and helps to detect problems. In order to avoid catastrophe at school campus, two different survey was performed. The first survey was about Personal Protective Equipment (PPE) for all students, and the second survey was

conducted for seniors of chemical engineering about their safety trainings of internship or Co-Op experiences and current problem of the ChE UO Lab. From those questionnaire surveys, it was possible to determine what they think about PPE and found current problems of the ChE UO Lab.

4.2 Personal Protection Equipment

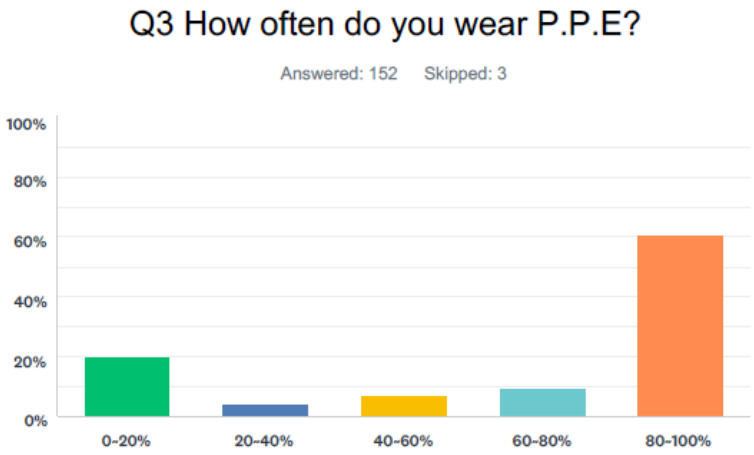
PPE protects individuals from safety risk and includes safety helmet, gloves, safety goggle, and steel toe boots. The reason PPE is important is that wearing PPE is the easiest way to protect and reduce damages from accident or incidents in the workplace and university laboratory. Depending on the laboratory, the required PPE may differ. The most common PPE at RHIT are the gown, safety goggles, and steel toe boots. Even though the PPE protect us from danger, wearing PPE during lab courses is somewhat annoying because they are not comfortable. Also, people tend to judge surroundings for themselves and consider the place to be safe without PPE. Due to this reason, people hesitate to wear PPE at work or in the laboratory. By definition, accidents suddenly happen at any time, and people do not know when they are coming. That is why people must always wear PPE at the required place.

Table 3. The list of questions asked for the PPE survey

	Questions
1	What is your major?
2	Have you taken or are you currently in lab course that requires wearing PPE?
3	How often do you wear PPE?
4	Were you asked to perform a risk and/or safety assessment at the beginning of course?
5	What is the primary reason for wearing PPE?
6	Were extra PPE available in the lab?

Knowing the importance of PPE, the questionnaire survey was administered to RHIT undergraduate and graduate student. The primary purpose of the first survey was to know students' thoughts about PPE during lab activities and performance of safety assessment. The survey was

available from April 20th to May 2nd, 2017, and 155 responses out of 2278 students were received, 6.8 % of entire RHIT students. As shown in Table 3, a total six questions were asked. Question 1 and 2 was used for a tool to categorize and screen participants. The entire result of the survey is shown in Appendix C.



ANSWER CHOICES	RESPONSES	
0~20%	19.74%	30
20~40%	3.95%	6
40~60%	6.58%	10
60~80%	9.21%	14
80~100%	60.53%	92
TOTAL		152

Figure 7. Result of Question 3 that shows percentage of wearing PPE during lab activities

Among the results of survey, an answer to review is how many students wear PPE during lab activities. As shown in Figure 7, 92 students, 60 percent of respondents, answered they wore PPE most of the time. The 70 percent of the 92 students were from Mechanical and Chemical Engineering. Based on the result, those two departments made sure their students wore PPE in the laboratory. However, it is difficult to say that other department did not manage students' safety in the laboratory. In addition, the requirement of PPE is different depending on which lab courses are required for students. Although students from same department, their projects and experiments might be different and require different PPE. Since students from Mechanical and Chemical

Engineering, and Chemistry majors deal with chemicals and metal equipment, they should wear at a minimum eye goggle and steel toe boots. However, the experiment performed in optical engineering and physics majors are relatively less dangerous than other majors' laboratories, and students could do experiments without any PPE.

ANSWER CHOICES	RESPONSES	
Self-protection	100.00%	28
Training	0.00%	0
Supervision	0.00%	0
Grading	0.00%	0
Other (please specify)	0.00%	0
TOTAL		28

Figure 8. Result of Question 5 of those who answered "0~20%" in Question 3

At this point, it is important to know students wear PPE in the laboratories. Even though lab instructors recommend and force to wear PPE during lab activities, some students may not follow the rules because wearing PPE, such as hard hat, eye goggle, and steel toe boots, is somewhat annoying and uncomfortable. In addition, students tend to consider surrounding is safe and decide not to wear PPE. From these reasons, student may feel PPE is unnecessary. Fortunately, RHIT students did think that way. Figure C5 shows that the majority students acknowledged the main purpose of PPE and think that PPE protects them from danger. As shown in Figure 8, students who

answered Question 3 with '0~20%' wore PPE for self-protection. In other words, those who answer '0~20%' did not wear the PPE because it is not required for the lab courses. Student must know that there are always hidden risks, which could not be found by self-evaluation of the surroundings, and the first step to avoid the risks is to wear appropriate PPE in the laboratory.

Table 4. The proportion of students who answered Question 6, 'Were extra PPE available in the lab?'

Major	A number of student who answered 'Yes' on Question 6	A number of student who answered 'No' on Question 6
ME[1]	38	12
ChE[2]	32	3
EE[3]	7	1
CE[4]	5	2
CSSE[5]	7	4
Biochemistry/Chem[6]	0	0
MA[7]	3	2
Biology	0	0
Physics	1	2
Others[8]	20	8

[1] Mechanical Engineering [2] Chemical Engineering [3] Electrical Engineering [4] Civil Engineering
[5] Computer Science & Software Engineering [6] Chemistry [7] Mathematics
[8] Engineering Management, Industrial Engineering, and Biomedical Engineering

Most lab courses asks student to purchase their own PPE, such as a hard hat and eye goggle, which is affordable. Assume that PPE was broken during lab activities. In order to continue experiment, they need additional PPE and the laboratory should have extra PPE that student can use just in case. Initially, Question 6 was asked to know whether academic laboratories have extra PPE for students or not. However, as shown in Table 4, 12 ME students, 24 percent of ME respondents, and few students answered 'No' in Question 6. There are three possible reasons. The first is laboratories actually do not have extra PPE for students. There are always extra PPE that someone left and did not pick up. Especially, ME laboratories supply eye goggles for students, and students are always able to access extra PPE if needed. Another reason is that students do not know the laboratories have extra PPE. This is possible because PPE is required to purchase individually, and

lab instructor may not tell that they have extra PPE. The other reason is the students answered the question with 'No' because PPE was not required in the lab courses. Those responses most likely came from the second and third reason.

The intention of this survey was to understand how RHIT students and faculty think about safety during lab activities. Even though some results were a bit vague, overall majority students acknowledged the importance of PPE and wore them where it is required. To establish a strong safety culture, not only lab instructors need to keep recommending wearing PPE, but also students should think their safety first and wear PPE in the laboratories.

4.3 Safety Training of Companies and Current Status of ChE UO Laboratory

The first part of the second survey was used to determine the most common method for safety training in the private sector. Companies make an effort to improve safety of employees and facilities. In order to do that, it is important to train employees and remind them of importance of safety. For IPL, visitor must watch several safety videos before they enter the plant, and EHS manages and train contractors to follow the safety rules. Also, they invite instructors to teach employees about new equipment safety techniques and procedures. Depending on the industry and company, training methods will vary. Knowing the most common safety training is not always the best, but it may be efficient to train employees with reputable approaches.

Another aspect of second survey is to uncover current problems in the ChE UO Laboratory. Even though faculties try hard to build a strong safety culture and protect students from unseen risks, it is difficult to know the problems without communication with students. As shown in Appendix B, IPL performed a survey to their employees in order to know their safety culture and find current problem of safety. The IPL survey is a model of the second survey, and performing a survey for

ChE students might give some ideas of current status of ChE UO Lab and directions to improve safety.

This survey was available for Chemical Engineering senior from January 4th to January 15th, 2018. 64 of 66 ChE senior students answered the questions. The reason of survey was subjected to senior student is they were in ChE lab courses and had chances to work in industry during summer internships or Co-Ops. Survey questions are shown in Table 5, a flow chart of survey is shown in Figure 9, and the result of the survey is shown in Appendix D.

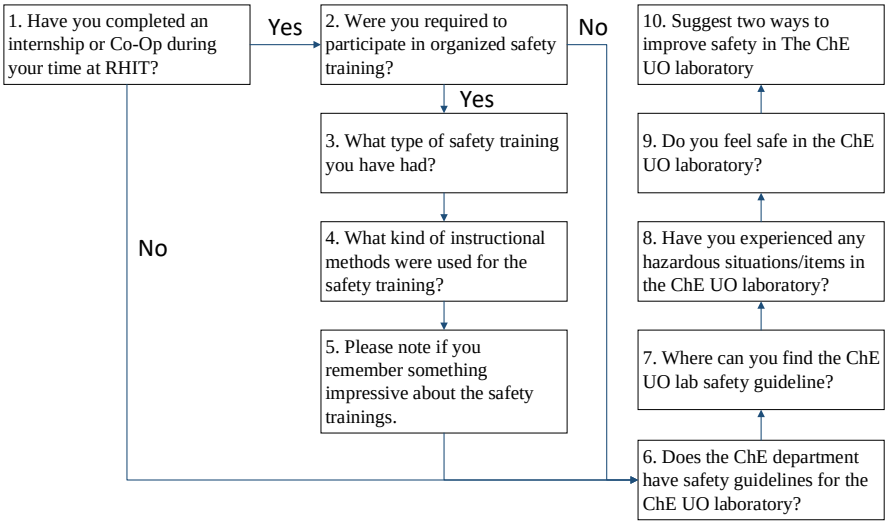


Figure 9. A flow chart of the safety training and ChE UO Lab survey.

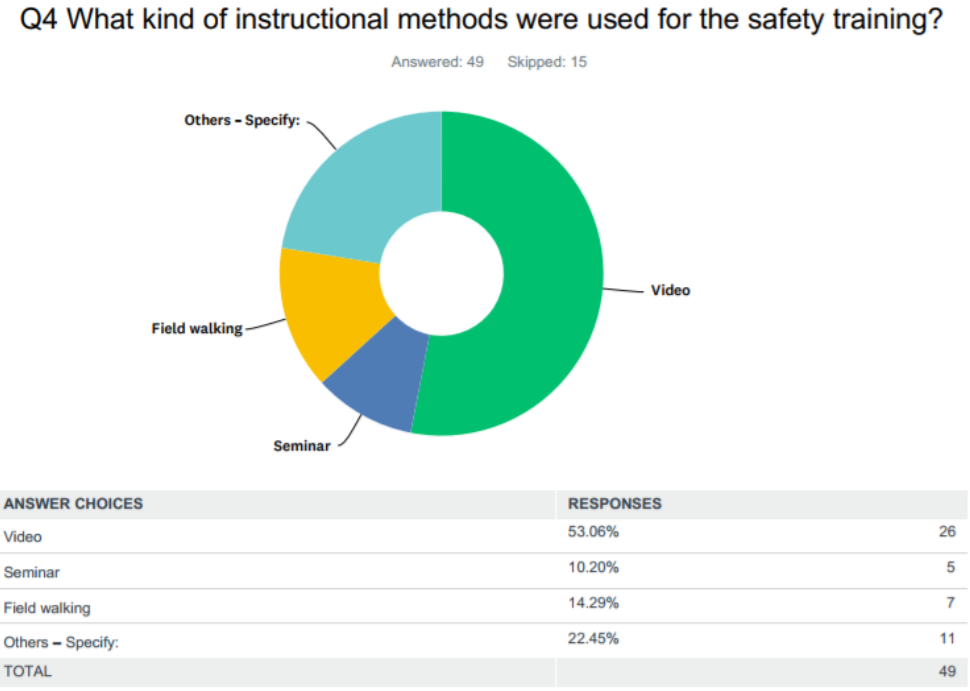
Table 5. The list of questions asked for the safety training and status of ChE UO Lab survey

	Questions
1	Have you completed an internship or Co-Op during your time at RHIT?
2	If yes, were you required to participate in organized safety training?
3	If yes, what type of safety training you have had?
4	What kind of instructional methods were used for the safety training?
5	Please note if you remember something impressive about the safety trainings.
6	Does the ChE department have safety guidelines for the ChE UO Laboratory?
7	Where can you find the ChE UO Lab safety guideline?

8	Have you experienced any hazardous situations/items in the ChE UO Laboratory?
9	Do you feel safe in the ChE UO Laboratory?
10	Suggest two ways to improve safety in ChE UO Laboratory

4.3.1 Safety Training of Companies

Data from senior ChE students show 49 students participated in work opportunities at industrial companies. Among those, more than 90 percent of students were required to participate a safety training. There were a myriad of topics of safety training, but simply it could be categorized in two: General Safety and safety training for given position. General safety training includes hot work, confined spaces, electrical shocks, and others. The result shows that most companies performed general safety training for internship and Co-Op students, and depending on the position, they trained students with position specific training, as shown in Figure D3, Appendix D.



ANSWER CHOICES	RESPONSES	
Video	53.06%	26
Seminar	10.20%	5
Field walking	14.29%	7
Others – Specify:	22.45%	11
TOTAL		49

*Others – Majority opinions were companies used both video and field walking.

Figure 10. A pie chart with common methods used for safety training in companies

Figure 10 shows that video is the most common tool used for safety training in companies. Companies may not have budgets to provide a seminar for employees and be difficult to set a

schedule for all employees. Video safety training is cost effective and flexible to train all employees. The second method is a field walking, which could give more detail information about safety to employees by directly observing and learn from environment. The third method used in companies is a seminar. Seminar is an effective way to educate employees to get professional safety information from an instructor, but due to financial problem, it would not be held often as videos. Another effective method is e-learning, which is used in IPL and efficient in time and cost as video training. The company gives employees certain periods to take an online class and associated assessments. Then, they must complete the given safety courses and the topics differ every time for the different types of safety information. According to a student comment, a company uses “safety bucks” as an incentive. The “bucks” are used to buy some prizes in the company. Employees who find safety problems and suggest ideas to improve safety earns the safety bucks.

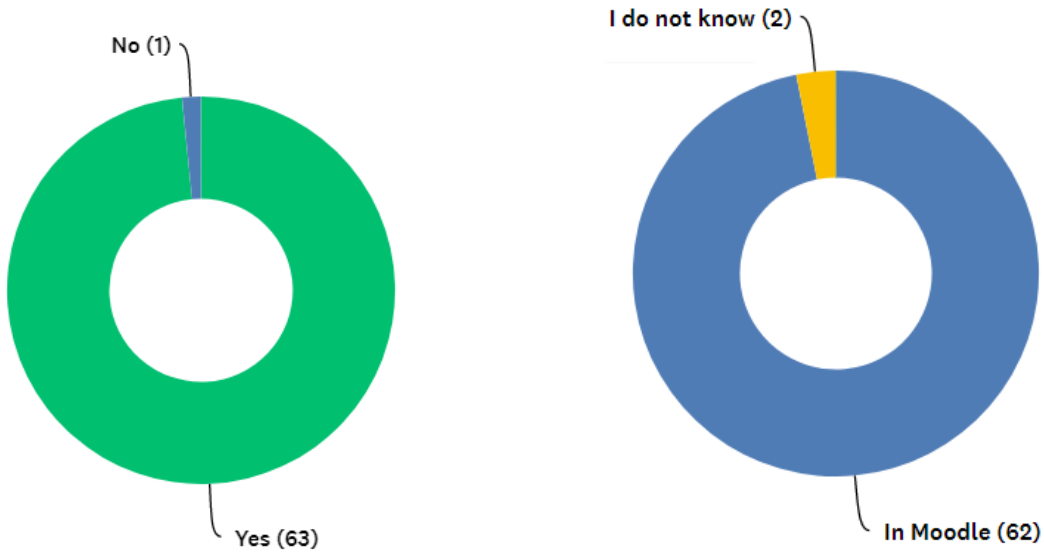
Companies train their employees in different ways. In this survey, companies used videos, field walking, and seminar most often. However, there is no right or wrong method to educate employees. Company may try a new method, such as ‘safety bucks’ and e-learning to find the best methods to train employees. It depends on industry, company, and culture. It is important that each company keeps making an effort with diverse ways to move forward for safety.

4.3.2 Current Status of ChE UO Laboratory

In order to complete the chemical engineering undergraduate program, all student must take three chemical engineering lab courses, which totals 11 credits. Students spend at least 8 hours per week in the ChE UO Lab, dealing with different kinds of equipment. In order to enter the ChE UO Lab, student must wear eye goggles, hard hat, and non-mesh shoes for self-protection. Since students spend a lot of time in the laboratory, they should feel safe in the lab. However, it seems there has

been no attempt to know what students think about the ChE UO Laboratory, unless they report risks or complain about facility. For this reason, the second part of the survey would give ideas for current problems and improvements.

The survey was started with asking questions whether they know about safety guideline of ChE UO Lab. During the lab activities, student might have a question of rules or regulations in safety before they do something. In this case, they need to look up and read regulations in the safety guideline. It would be best if all students read through the safety guideline, but it is still good that students know the location of safety guideline when they are needed. Even though one or two students did not know about the safety guideline, Figure 11a and 11b shows that a majority students recognized where to find the safety guidelines.

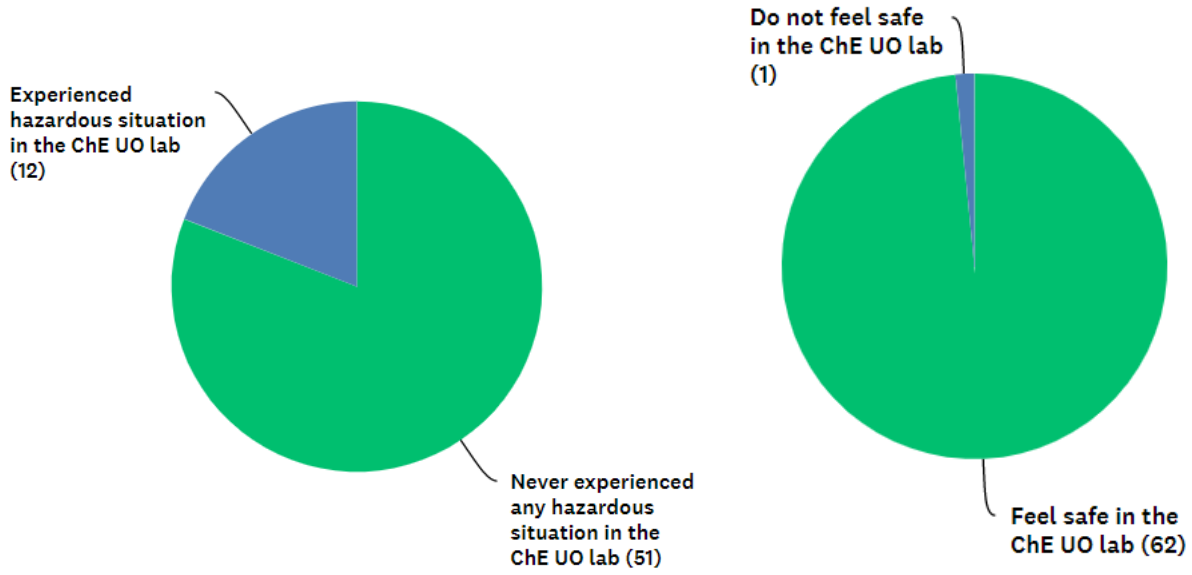


(a) (b)

Figure 11. (a) The result of Question 6, the existence of the safety guideline and (b) The result of Question 7, the location of the safety guideline

This result may be influenced by safety analysis posted in the Moodle. At the beginning of every quarter, student must complete the safety analysis for the given experiment. They submit a safety

report with detailed surrounding information, such as location of closest exit, fire extinguisher, eye wash, and the like. Also they analyze the fire, explosion, steam, and electrical risks of equipment. While working on the safety analysis from Moodle, they can increase their knowledge from the guidelines.



(a) (b)

Figure 12. (a) The result of Question 8, hazardous situation in the ChE UO Lab and (b) The result of Question 9, feeling for the ChE UO Lab

As previous mentioned, the ultimate goal is to make the laboratory safe so students feel comfortable working in the space. The place. Figure 12b shows that students feel safe at the ChE UO Lab, however, as shown in Figure 12a, a few students experiences hazardous situation during lab activities. For Question 9, students had to choose either 'Yes' or 'No'. If they were asked to rate the safety of the ChE UO Lab, then the result may be around 3 to 4 out 5, based on the responses on Question 8. All other responses from Questions 8 and 9 are found in Appendix D.

From the survey, the author learned a majority of students experienced hazardous situations from equipment and chemicals they used. A students left a comment that instructors need to perform a

medical survey for a project. Some students might have an allergy to certain chemicals and materials. The fact is that the department has not asked about students' health concerns. Students usually come and talk for something when they have a problem. It seems to be reactive. It would be a better idea to mention "Send an email to instructor if you have any health problems" or actually distribute a medical survey before assigning the projects lab course. Since students are required to perform the experiment, the department should take a practice approach to minimize concerns. Knowing students feel unsafe and worry about their safety, faculty and technicians may provide Material Safety Data Sheet (MSDS) for chemicals and announce the precaution of the equipment's safety before they start projects.

Students may or may not know, but faculty take efforts to improve students' safety. Before 2016, lab instructors verbally shared the safety information, which caused inconsistencies between lab instructors. It was difficult to communicate with several instructors at the same time, unless they coordinated their efforts. When a problem was found during lab activities, instructors would find other instructors and informally spread the word. Also when they later reviewed the case, it was almost impossible to maintain information. In order to resolve this problem, starting in 2016, faculty have used SharePoint to deliver the information. Instructors could post safety problems they found and what accidents happened in the laboratory, and other faculties also could see the post and leave their opinions in order to avoid same incidents and resolve the problems. In this case, they are able to check the historical problems experienced in the lab. In addition, every other weeks, the ChE department hold meetings for updates. During the meeting, lab instructors could bring up the current problems and discuss solutions. It is good to have a chance to share their opinions and solve the problems with other faculty. During any time of week, if a problem needs

to be discussed, they can adjust schedules and do their best to remove the risks. In addition, they started to create SOP for students. The SOP made it easy for students to perform the exercises.

Despite the efforts of the ChE department, there are always problems they could not solve because they look at the problem from the view of an instructor. In order to make the ChE UO Lab safer, students also suggested idea to improve safety in the ChE UO Lab. All responses were helpful to understand current problems and they are summarized below.

- Make “more space between projects to prevent clutter and tripping hazards”
- Print out the safety protocol and place it in the lab
- Take the online safety course from AIChE
- Clearly announce possible dangerous situations before students start the equipment
- Put ‘Exit’ signs on all the doors for emergency egress
- Watch the safety videos and take a test or quiz about safety of the ChE UO Lab
- Use ear plugs for noise
- Move the lockers to upstairs
- Set up the emergency shut off switches for equipment
- Perform a medical/allergen survey for all students prior to assigning lab projects

Most of suggestion were doable with some time and effort to change, and some suggestion were in process, such as making more spaces and moving the lockers. Currently, the department is plans to buy new cabinets to house belongings so that students only could have to their laptops in the laboratory.

From this survey, it clearly showed how students felt about the laboratory safety. Overall, the department has managed well, but there are still problems to resolve and improve. Based on students commented and their options to improve the laboratory condition, changes are needed immediately to fix more problems.

5. Conclusion and Future Work

Many chemical, pharmaceutical, and related companies focus on PSM. Especially, safety culture recently has been highlighted as an important element in PSM and as one of the essential factors to reduce accident rate at workplace. Companies have emphasized the safety culture because they know that a small problem could cause a dangerous situation depending of employees' behavior and habits. For this reason, companies have attempted to hire employees based on the company's vision, goal, and culture. Additionally, employees are trained to operate the process without any accidents and troubles. IPL's safety culture shows what IPL does for improving the safety of employees and the plant. One method, safety survey, used was applied to RHIT in order to understand the safety culture and find problems.

The result showed the safety culture in RHIT is strong. Students acknowledged the importance of PPE and wore them during lab activities despite of its discomfort. The majority of chemical engineering senior students knew where to find the safety guidelines and felt safe at the laboratory, where they spend eight hours every week. However, a few students mention problems to solve. Since all chemical engineering faculty always try to make student feel safe and improve the safety in the laboratory, they would change safety practices based on students' opinions.

It is not appropriate to directly evaluate an academic laboratory with all PSM regulations, which are mainly for the private sector. However, some elements of PSM could be used for reference to obtain some idea to improve in safety. Faculty would never know what students feel and how they think about safety of laboratory until they come and speak to faculty. In order to know their thoughts and opinions, it is important keep communicating and getting feedback from students. This is the first time to survey student's safety perception in the laboratory, and as a result, good aspects and problems were found. If the Institute regularly performs the safety survey and tries

hard to keep the good aspects with solving the problems found, students would feel safer during lab activities and have right safety perception, which is a basis of a strong safety culture.

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Appendix A. Elements Related to Process Safety Culture in OSHA

1. Compliance with Standards

All processes should follow the standards which include federal regulations and laws, national and international codes, and internal and external standards. The information should be accessible to potential users. CCPS RBPS states, "The standards system will help the company to operate and maintain a safe facility, consistently implement process safety practices, and minimize legal liability [2]." In addition, the standards system is used in audit program to evaluate PSM performance. OSHA's process safety information which includes the standards system of CCPS RBPS suggests that the employer an employee should perceive the process information. The process information must include information on the hazardous chemicals used or produced from the process, the technology of the process, or equipment in the process as shown in Table A1. Acknowledging the process information in advance helps to raise awareness of process safety and to develop the process hazard analysis [2].

Table A1. Details of Process Safety information of OSHA PSM

Chemicals	Technology	Equipment
Toxicity	Process flow diagram	Materials of construction
Permissible exposure limits	Process chemistry	Piping and instrument diagram (P&IDs)
Physical data	Maximum intended inventory	Electrical classification
Reactivity data	Safe limits for temperatures, pressures, flows, or compositions	Relief system design and design basis
Corrosivity data	An evaluation of the consequences of deviation	Ventilation system design
Thermal and chemical stability data		Design codes and standards employed
Hazardous effects of inadvertent mixing of different materials		Material and energy balance for processes
		Safety systems

2. Process Safety Competence

The competence of operator is an important role because human error is one of the factors of PSM failure. If the operator's responses to an emergency are not appropriate, the situation could become a serious accident, which causes enormous damage. To avoid this situation, operators should have sufficient knowledge about the processes, safety, and equipment. The processes should be performed in accordance with the SOP and the employees should know how to react when unexpected events occurr, be able to control equipment, and recognize risks in advance. To ensure process safety, the company should regularly provide training opportunities for practicing and testing their professional competence and process understanding. The company must ensure that the training is provided to appropriate people, appropriate information is provided to them, and the competence acquired from the training is consistently applied to the process to secure the safety.

3. Workforce Involvement

To secure the safety of process, engineers and workers must be aware of the roles, responsibilities, and what they are capable. However, some workers do not perfectly understand the process or underestimate the importance of responsibilities in their position. Since serious situations could be caused by small mistakes from the workforce, workers must have expert knowledge in the process, learned from experience. Lack of understanding in the responsibility and competence directly increase the risk in process safety. Therefore, workers must acknowledge the information about the equipment and process so that they could cope with emergencies and maintain the process and equipment.

4. Stakeholder Outreach

Stakeholder outreach is to search individuals and organizations, closely related to their company operation to share about process safety information, establish a relationship with community organizations, professional groups, and other companies, and share credibility information with appropriate stakeholders [2]. Before sharing information with others, they have to ensure it is accurate information by checking their process and data. Through inspecting their own data, the organization could find mistakes, fix them, and improve their process safety. By sharing information about process safety with other companies, they could improve their process safety, and the organizations could help each other to resolve problems and suggest helpful ideas to improve process safety. Also, the public can be a stake holder. By opening the sources about process safety to public, organizations could make people think that they are protected by the companies and their process is safe to trust.

5. Process Knowledge Management

Process knowledge is all information about the entire process including the risk associated with the process. For example, engineering drawing and calculation, specifications for designs, installations of process equipment, and selection of safe operating limits can be the process knowledge [2]. It is important what information they document into a company's database, such as hazardous chemicals and cautious processes; however, the company needs to make sure that the information is accurate. In addition, the documents must be readable and understandable by workers. If the information developed by R&D is different from the document, then the worker would inappropriately control the process, which could cause a disaster.

6. Hazard Identification and Risk Analysis

Hazard identification and risk analysis (HIRA) should be performed throughout the entire process to ensure safety of employees, the publics, the environment. As previously mentioned in the introduction, risk can be analyzed in the three following categories: hazard, consequences, likelihood. Various risk can be categorized by those three factors. First step of HIRA is to identify possible risks in the process, then the risks are evaluated and analyzed to find ways to eliminate before accidents. Companies performed internal HIRA based on OSHA PSM principles. FMEA, Failure modes, and HAZOP are used as typical tools of HIRA. Depending on industry, it might need to perform the risk analysis of explosion, which has a low likelihood.

7. Operating Procedure

Operating procedure encompasses written instruction for process, description of process, hazard, equipment, control, and shooting trouble. Operating procedure should describe the context in detail so that operators could exactly follow the steps. In addition, procedure should include emergency situation, such as emergency procedure when pump is out of service. Without detail description, operator could operate the process with inappropriate procedure. Therefore, each step should be explained in detail. Once a procedure is created, every operators must follow the instruction with no exception, so that the equipment and process can be executed with the intended manner. When the procedure is required to be modified, process engineers, operators, and related employees must participate to develop the procedure together so that it can be modified and evaluated with different perspective, and supervisors and managers must review it before it is used.

8. Asset Integrity and Reliability

To remove risks, organization must make sure that equipment designed properly, installed at the right place in accordance with specifications. Inappropriate installations and design and material of equipment definitely contain high risks. Especially, in the chemical industry, corrosive contents damage pipeline and reduce the durability of pipes and equipment, which could lead a leakage and explosion. Therefore, equipment requires regular inspections and replacements if it is applicable. Asset integrity encompasses inspections, tests, and maintenances, and by doing those, it makes sure the safety equipment operates during an emergency and the overall system is reliable. This asset integrity and reliability activities should be performed on a daily basis by operators, mechanical engineers, process engineers, and the like. Mechanical engineers oversee maintenance of equipment, and process engineers oversee the inspection of abnormal odors, sound, and conditions.

9. Contractor Management

It is difficult for an organization to manage overall process. By cooperating and distributing works with other company, a company can manage the process more efficiently. For this reason, how the organization selects and manages contractors is important. The more contractors involved in a project, the more complicated the project would be and likely lose control, without excellent management of course. Working with contractors, which have a lack of specialized skills and less experiences, might increase potential risks in the process. Contractor management is to ensure the services from contractors do not increase potential risk of the process safety in the organization.

10. Training and Performance Assurance

Training employees is a practical method to improve process safety. Training makes employees acknowledge the importance of the process safety, safety instructions, task requirements, and duties for safety. In addition, performance assurance is a method to evaluate whether employees understand required duties and knowledge from training and are able to apply them in actual situations. Through the evaluation, organizations can determine if additional training is required to secure their process safety. Since the emergency planning and responds are different from each position, the required training must be different. The training and performance assurance might take place in a classroom or workplace.

11. Management of Change

The purpose of the management of change (MOC) is to assess the risks from changes and reduce the risk. The MOC prevents changes in equipment, procedure, and process that could increase the potential risks. Reviews and evaluations of proposed changes of equipment, organization structure, activities, and design facilities before implementation are considered by the MOC. Unless appropriate reviews prior to implementation, it will increase the risks of process. The requested changes from individuals at the work place are delivered to project teams and organizations, and those teams and organizations review the requests whether the request is harmful to the process. They could deny the changes because the changes increase significant amount of risks or allow to change them because the changes do not affect or even decrease risks. However, the review process should not be performed by one person because the person may miss essential factors and reviews

from diverse people may detects other unseen risks. After approval of changes, the change must be delivered to relevant employees and performed as it is.

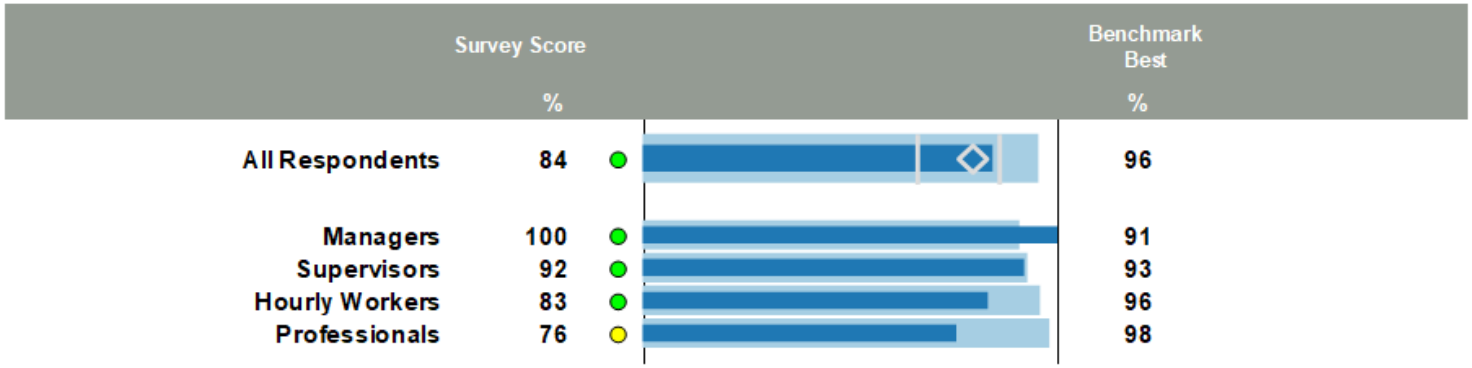
12. Operational Readiness

Operational readiness is a step to determine the facilities and process are safe to startup from shutdown. For certain cases, such as maintenance, replacement, modified process, and inspection, it is required to shut down partial or entire processes and facilities. If the process was modified or a new process were adopted, the safety of the process must be ensured. The new and changed process must go through the MOC review to assure the safety of process. Also, engineers and operators must make sure that there are no leakages and uncompleted maintenances. Depending on the size of project, the duration of shutdown may differ from a few hours to a few weeks. No matter how long the shutdown is, the operational readiness must be guaranteed. Depending on the complexity of process, operational readiness requires a various number of people to check the conditions of the system before startup. It could be just an exterior checking, but it could have evaluations in the perspective of engineering, quality, operations, and design. Extensive checklists, multi-stage verification, and multiple functional sign-offs are a typical process to authorize startup [2].

Appendix B. The Example Report of Safety Perception Survey Performed by DuPont

Question 1: Indicate the priority you personally give to safety.

Percent of respondents that ranked safety first:



All Responses

Percent of Respondents:	Managers %	Supervisors %	Hourly Workers %	Professionals %	All Respondents %
First <	100	92	83	76	84
Second	0	2	1	15	3
Third	0	0	4	0	3
Fourth	0	6	11	9	9
Count of Responses Above:	5	50	157	33	245

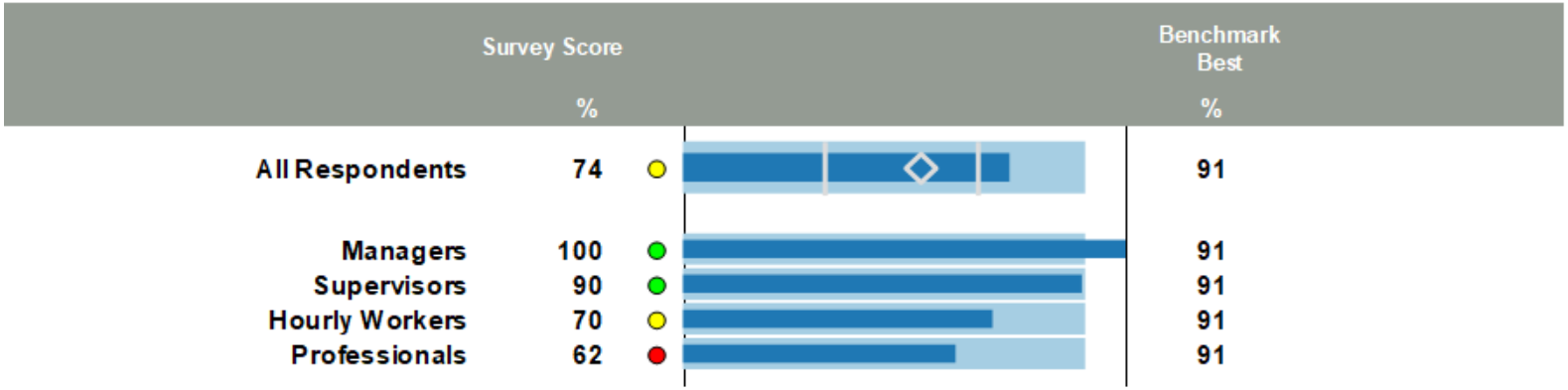
< Indicates what response or responses are grouped together for Benchmarking.

DuPont Sustainable Solutions

Report: IPL - Petersburg Created: 28Jun2017 Survey: AES Corporation 2017 Survey

Question 2: Indicate the priority that others give to safety.

Percent of respondents that said others ranked safety first:



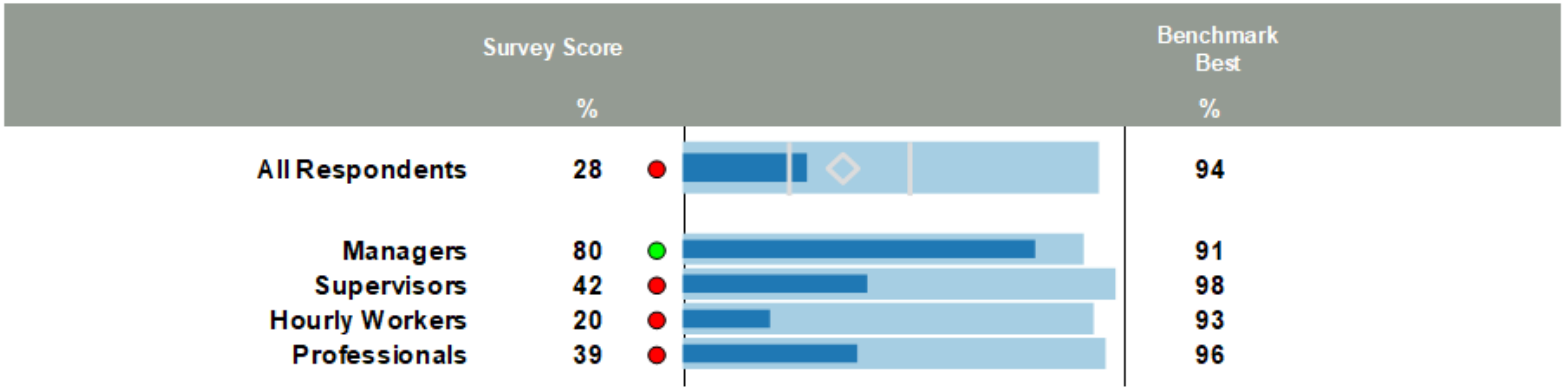
All Responses

Percent of Respondents:	Managers %	Supervisors %	Hourly Workers %	Professionals %	All Respondents %
Selves	100	92	83	76	84
Managers <	100	88	59	67	67
Supervisors <	100	88	66	55	70
Hourly Workers <	100	94	85	64	84
All Respondents	100	90	70	62	74
Count of Responses Above:	5	50	158	33	246

< Indicates what response or responses are grouped together for Benchmarking.

Question 3: To what extent can injuries be prevented?

Percent of respondents answering that all injuries can be prevented:



All Responses

Percent of Respondents:	Managers %	Supervisors %	Hourly Workers %	Professionals %	All Respondents %
All <	80	42	20	39	28
Almost All	20	48	58	48	54
Many	0	10	20	9	16
Some	0	0	2	0	1
Few	0	0	1	3	1
Count of Responses Above:	5	50	158	33	246

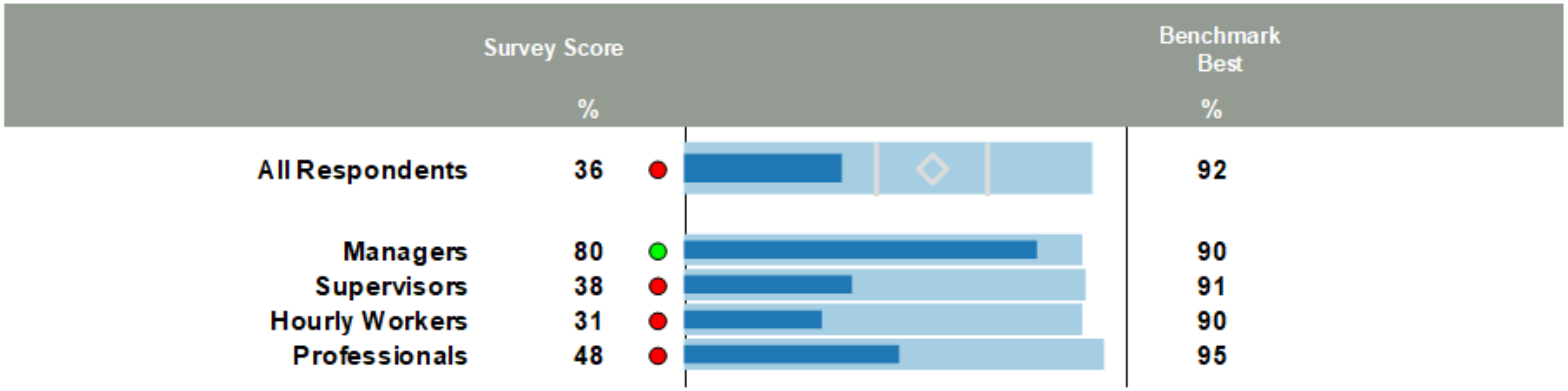
< Indicates what response or responses are grouped together for Benchmarking.

DuPont Sustainable Solutions

Report: IPL - Petersburg Created: 28Jun2017 Survey: AES Corporation 2017 Survey

Question 4: How would a strong, long-term effort for safety excellence affect excellence in other areas, such as quality, productivity, costs, and profits?

Percent of respondents answering that the safety effort will be very helpful:



All Responses

Percent of Respondents:	Managers %	Supervisors %	Hourly Workers %	Professionals %	All Respondents %
Be Very Helpful <	80	38	31	48	36
Provide Some Help	20	40	36	30	36
Have No Effect	0	6	6	3	5
Make It Harder	0	14	25	9	20
Weaken Our Ability	0	2	3	9	3
Count of Responses Above:	5	50	158	33	246

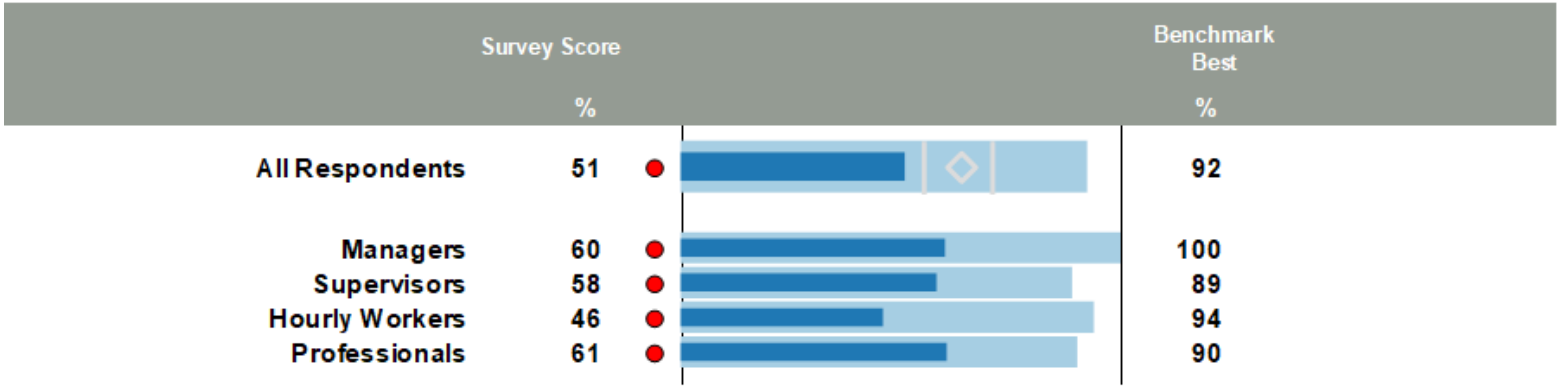
< Indicates what response or responses are grouped together for Benchmarking.

DuPont Sustainable Solutions

Report: IPL - Petersburg Created: 28Jun2017 Survey: AES Corporation 2017 Survey

Question 5: At what point does safety improvement cost more than the economic benefits it provides? (Possible economic benefits of safety are reduced costs of injuries and lost working time, better morale and product quality, improved production, etc.)

Percent of respondents answering that within reason there is no limit:



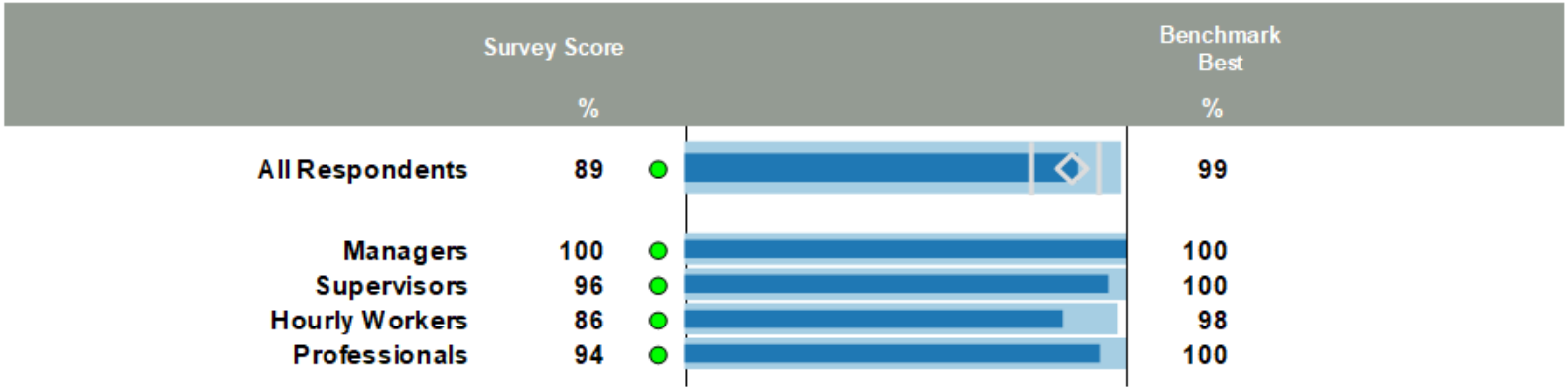
All Responses

Percent of Respondents:	Managers %	Supervisors %	Hourly Workers %	Professionals %	All Respondents %
No Limit <	60	58	46	61	51
Excellent Safety	40	28	23	15	23
Good Safety	0	8	21	15	17
Average Safety	0	4	5	0	4
Always A Net Cost	0	2	5	9	5
Count of Responses Above:	5	50	154	33	242

< Indicates what response or responses are grouped together for Benchmarking.

Question 7a: Does your organization have well-established, readily available, written safety values (beliefs and principles)?

Percent of respondents answering that safety values do exist:



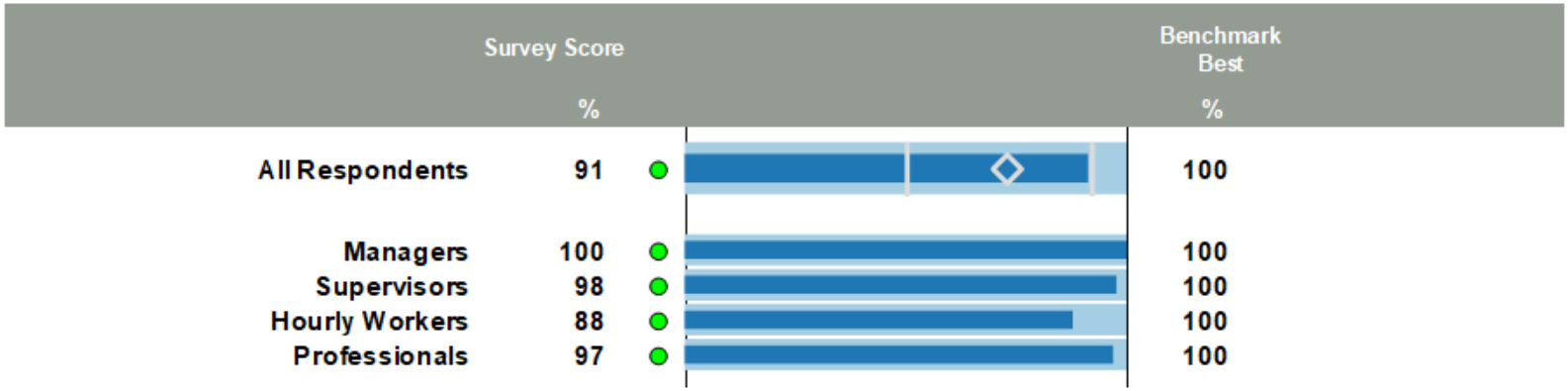
All Responses

Percent of Respondents:	Managers %	Supervisors %	Hourly Workers %	Professionals %	All Respondents %
Yes <	100	96	86	94	89
No	0	0	8	0	5
Don't Know	0	4	7	6	6
Count of Responses Above:	5	48	153	33	239

< Indicates what response or responses are grouped together for Benchmarking.

Question 12a: How often are safety meetings held in your workplace?

Percent of respondents who say safety meetings are held weekly, bi-weekly, or monthly:



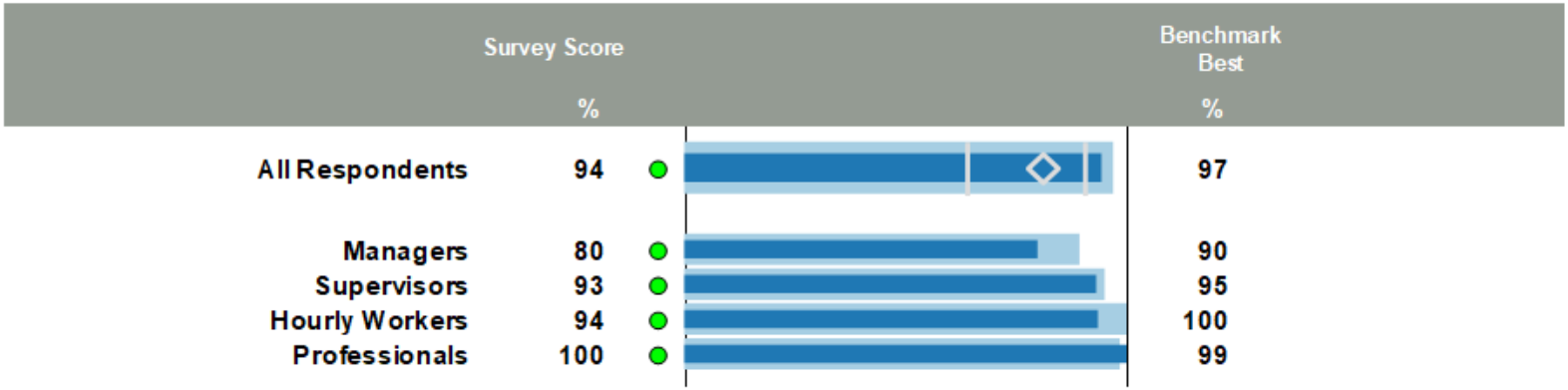
All Responses

Percent of Respondents:	Managers %	Supervisors %	Hourly Workers %	Professionals %	All Respondents %
Weekly or Every Two Weeks <	40	4	9	9	9
Monthly <	60	93	79	88	82
Every Two Months	0	0	1	0	1
Less Than Every Two Months	0	2	5	0	4
Never	0	0	5	3	4
Count of Responses Above:	5	45	149	32	231

< Indicates what response or responses are grouped together for Benchmarking.

Question 12b: Do you attend the safety meetings regularly?

Percent of respondents answering that they attend safety meetings:



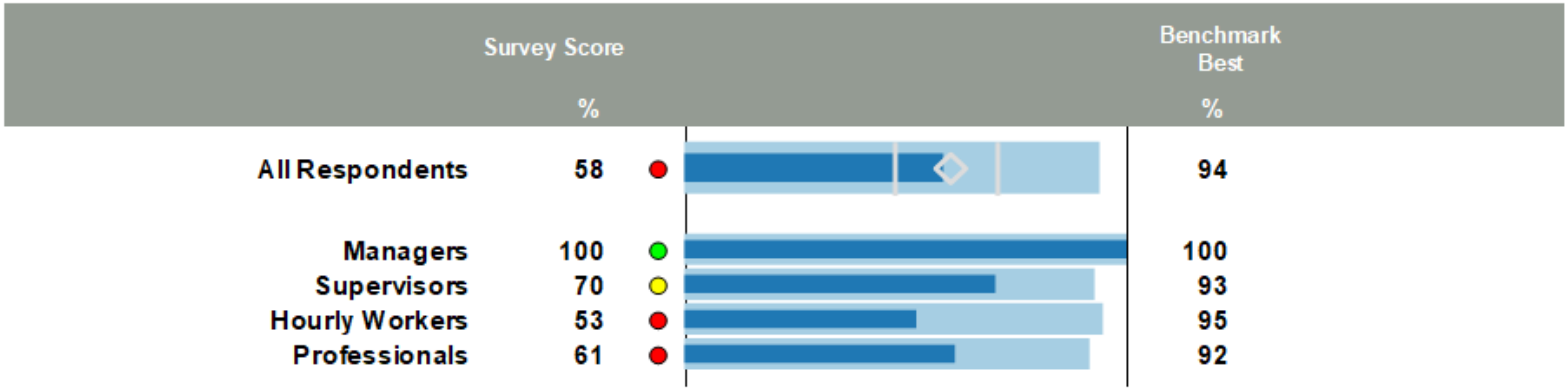
All Responses

Percent of Respondents	Managers %	Supervisors %	Hourly Workers %	Professionals %	All Respondents %
Yes <	80	93	94	100	94
No	20	7	6	0	6
Count of Responses Above:	5	45	141	31	222

< Indicates what response or responses are grouped together for Benchmarking.

Question 12c: How do you rate the quality and effectiveness of the safety meetings?

Percent of respondents who say safety meetings are excellent or good:



All Responses

Percent of Respondents:	Managers %	Supervisors %	Hourly Workers %	Professionals %	All Respondents %
Excellent <	40	14	10	6	11
Good <	60	57	42	55	47
Satisfactory	0	25	35	29	31
Poor	0	5	7	10	7
Very Poor	0	0	6	0	4
Don't Know	0	0	0	0	0
Count of Responses Above:	5	44	139	31	219
"I Don't Know" Responses Excluded:	0	1	2	0	3

< Indicates what response or responses are grouped together for Benchmarking.

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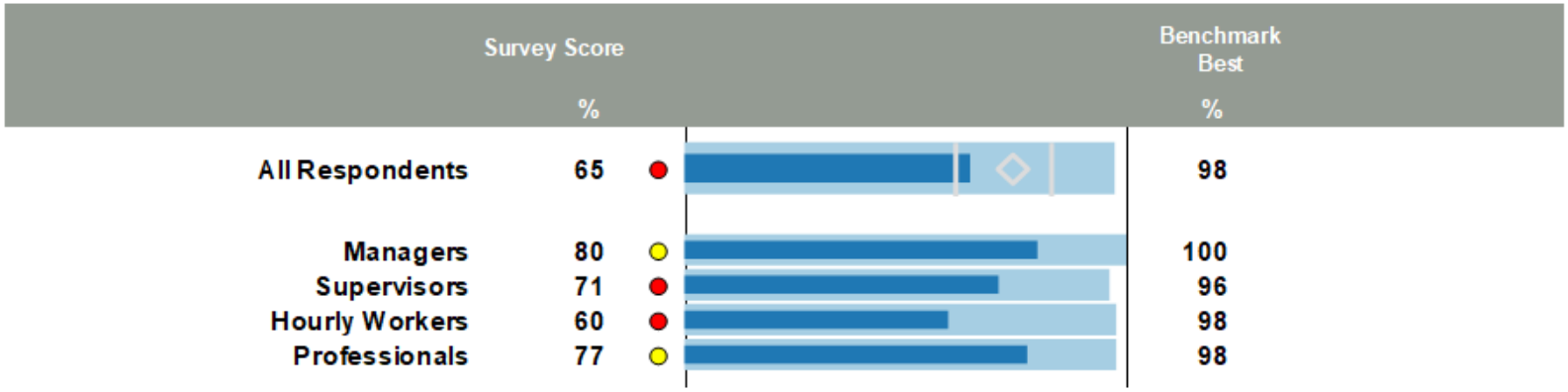
Report: IPL - Petersburg Created: 28Jun2017 Survey: AES Corporation 2017 Survey

Question 13a: What is the quality of the safety rules in your organization? High-quality rules are up-to-date and clearly written and help people do their work well and safely.

Percent of respondents who say quality of rules is excellent or good:



All Responses

Percent of Respondents:	Managers %	Supervisors %	Hourly Workers %	Professionals %	All Respondents %
Excellent <	60	29	17	23	21
Good <	20	42	42	55	44
Satisfactory	20	22	27	23	25
Poor	0	7	10	0	7
Very Poor	0	0	4	0	3
Don't Know	0	0	0	0	0
Count of Responses Above:	5	45	146	31	227
"I Don't Know" Responses Excluded:	0	0	2	1	3

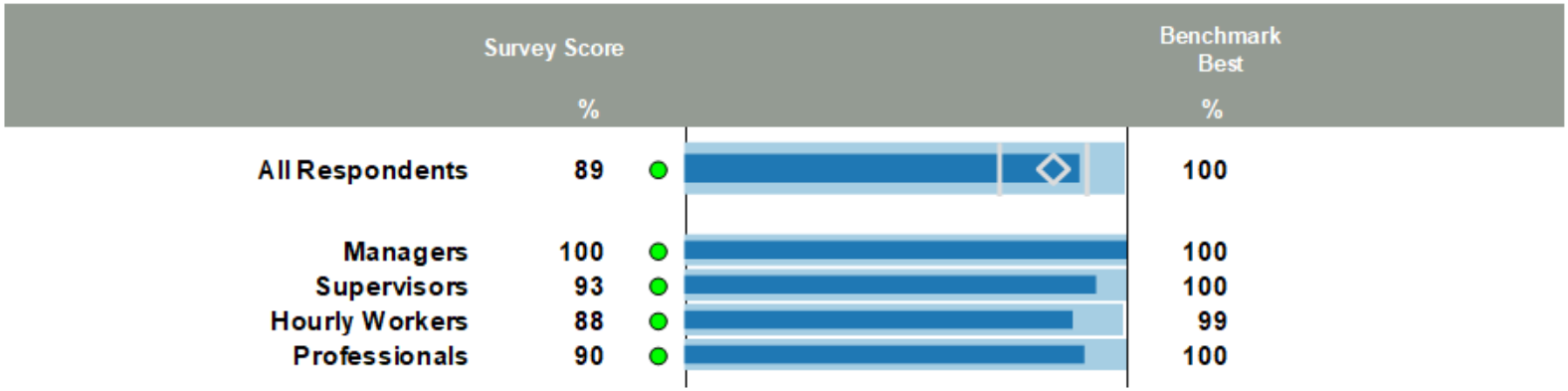
< Indicates what response or responses are grouped together for Benchmarking.

DuPont Sustainable Solutions

Report: IPL - Petersburg Created: 28Jun2017 Survey: AES Corporation 2017 Survey

Question 13b: To what extent are the safety rules of your organization obeyed?

Percent of respondents who say safety rules are obeyed without exception or generally:



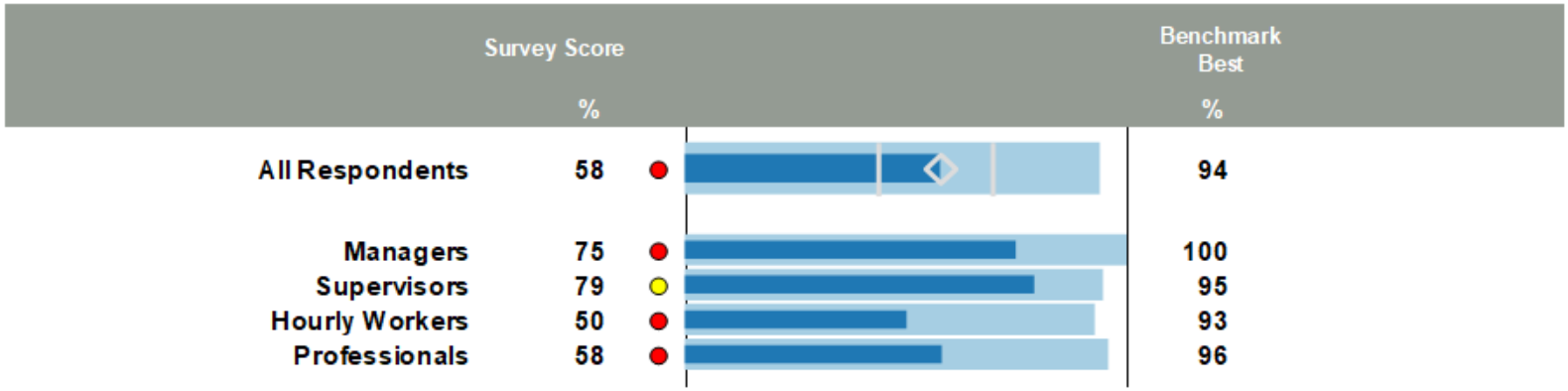
All Responses

Percent of Respondents:	Managers %	Supervisors %	Hourly Workers %	Professionals %	All Respondents %
Without Exception <	0	18	21	16	19
Generally Obeyed <	100	76	67	74	70
Sometimes Followed	0	7	11	6	9
Often Not Obeyed	0	0	1	3	1
Rarely Obeyed	0	0	0	0	0
Count of Responses Above:	5	45	146	31	227
"I Don't Know" Responses Excluded:	0	0	1	1	2

< Indicates what response or responses are grouped together for Benchmarking.

Question 16b: How do you rate the quality and effectiveness of the safety audit and inspection system? Consider frequency, thoroughness, extent of participation, extent to which safety behavior (not just physical conditions) is observed, thoroughness of the follow-up, and overall effectiveness in helping to develop a safer workplace.

Percent of respondents who rated the quality of the safety audits as excellent or good:



All Responses

Percent of Respondents:	Managers %	Supervisors %	Hourly Workers %	Professionals %	All Respondents %
Excellent <	75	26	10	13	15
Good <	0	53	40	45	43
Satisfactory	25	19	30	29	27
Poor	0	2	16	10	12
Very Poor	0	0	4	3	3
Count of Responses Above:	4	43	124	31	202
"I Don't Know" Responses Excluded:	0	0	23	1	24

< Indicates what response or responses are grouped together for Benchmarking.

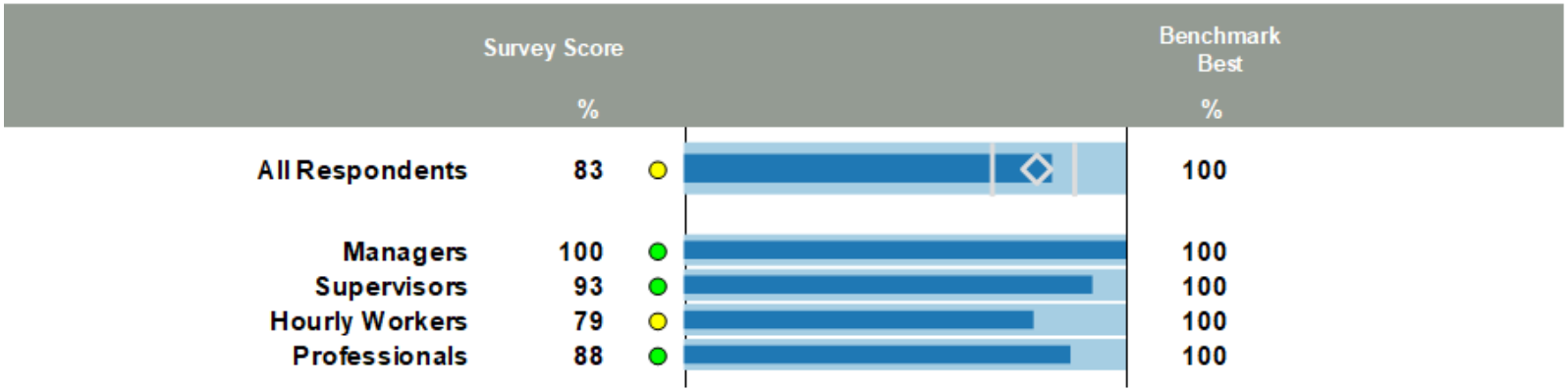
* To ensure confidentiality, responses from groups with less than 3 respondents are not shown.

DuPont Sustainable Solutions

Report: IPL - Petersburg Created: 28Jun2017 Survey: AES Corporation 2017 Survey

Question 21: How well do you know your organization's safety goals and performance?

Percent of respondents who have full or company only knowledge is:

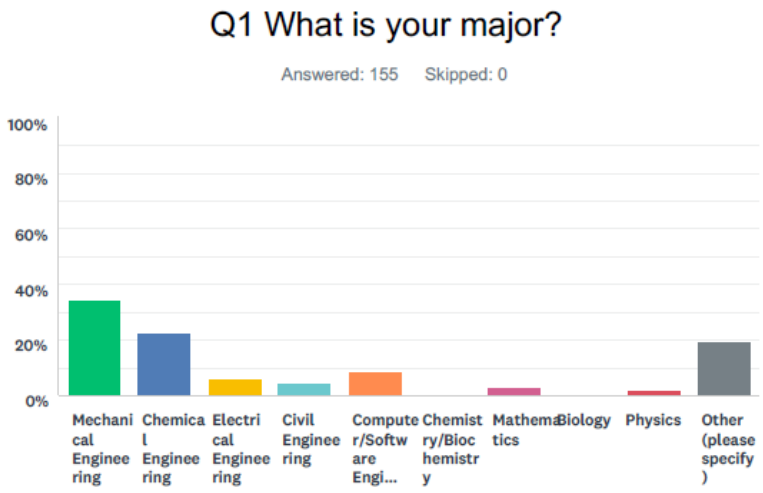


All Responses

Percent of Respondents:	Managers %	Supervisors %	Hourly Workers %	Professionals %	All Respondents %
Full Knowledge <	100	48	28	34	34
Own Company Only <	0	45	51	53	49
General Knowledge	0	8	19	9	15
No Knowledge	0	0	2	3	2
Count of Responses Above:	4	40	143	32	219

< Indicates what response or responses are grouped together for Benchmarking.
* To ensure confidentiality, responses from groups with less than 3 respondents are not shown.

Appendix C. Summary of Personal Protective Equipment Survey

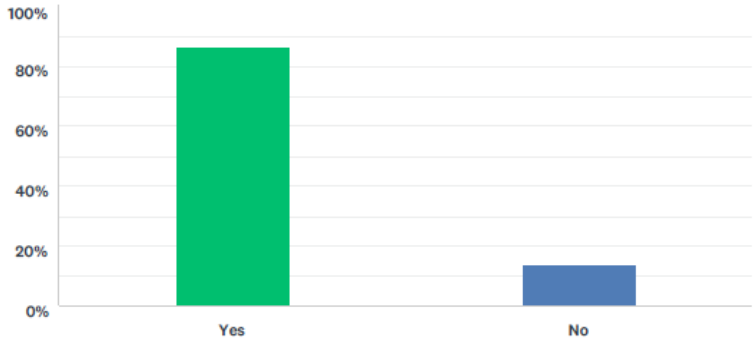


ANSWER CHOICES	RESPONSES	
Mechanical Engineering	34.19%	53
Chemical Engineering	22.58%	35
Electrical Engineering	5.81%	9
Civil Engineering	4.52%	7
Computer/Software Engineering	8.39%	13
Chemistry/Biochemistry	0.00%	0
Mathematics	3.23%	5
Biology	0.00%	0
Physics	1.94%	3
Other (please specify)	19.35%	30
TOTAL		155

Figure C1. Summary of Question 1 responses

Q2 Have you taken or are you currently in a lab (physics, chemistry, mechanical, civil, etc.) course that requires wearing personal protection equipment (PPE)?

Answered: 155 Skipped: 0

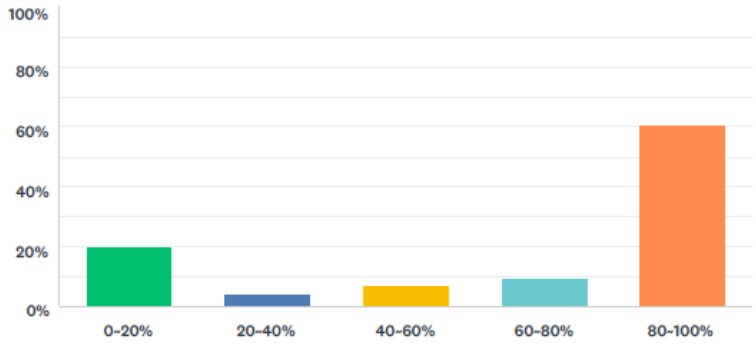


ANSWER CHOICES	RESPONSES	
Yes	86.45%	134
No	13.55%	21
TOTAL		155

Figure C2. Summary of Question 2 responses

Q3 How often do you wear P.P.E?

Answered: 152 Skipped: 3

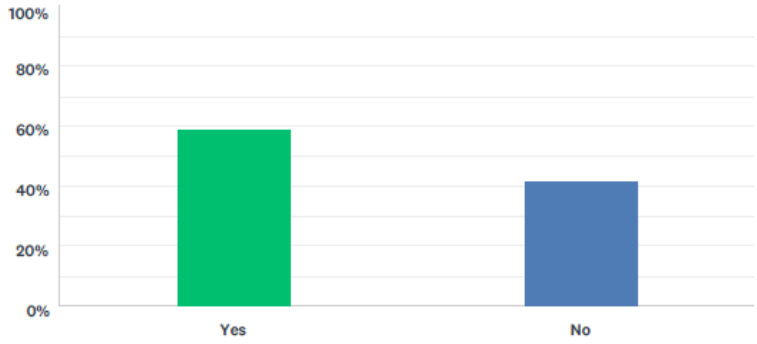


ANSWER CHOICES	RESPONSES	
0~20%	19.74%	30
20~40%	3.95%	6
40~60%	6.58%	10
60~80%	9.21%	14
80~100%	60.53%	92
TOTAL		152

Figure C3. Summary of Question 3 responses

Q4 Were you asked to perform a risk and/or safety assessment at the beginning of course?

Answered: 150 Skipped: 5



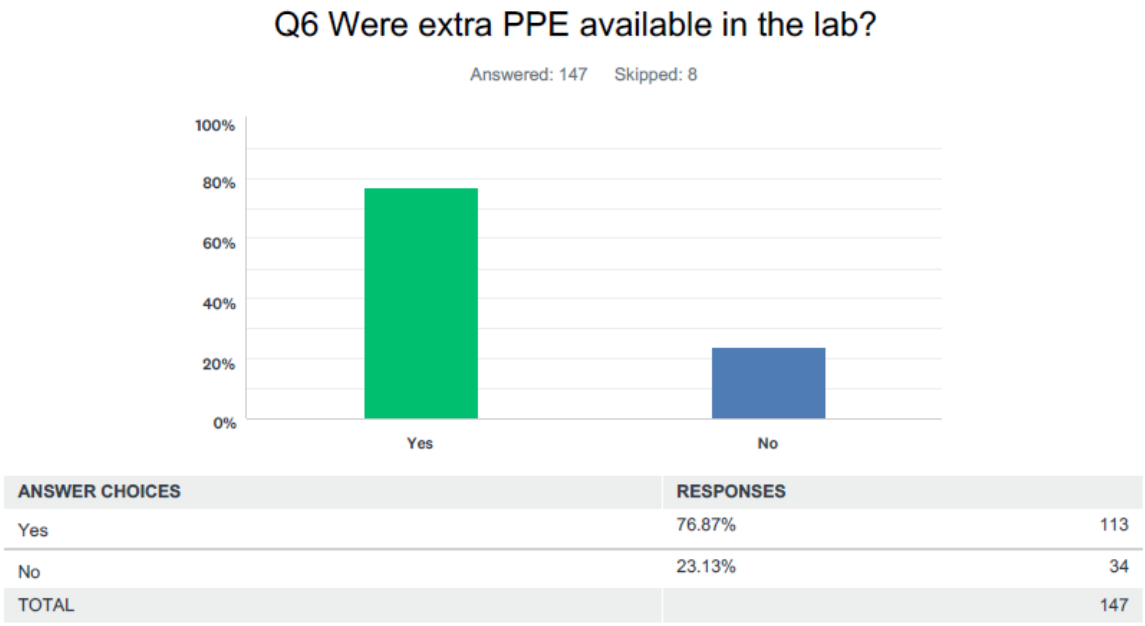
ANSWER CHOICES	RESPONSES	
Yes	58.67%	88
No	41.33%	62
TOTAL		150

Figure C4. Summary of Question 4 responses

w

ANSWER CHOICES	RESPONSES	
Self-protection	94.04%	142
Training	3.31%	5
Supervision	1.99%	3
Grading	0.00%	0
Other (please specify)	0.66%	1
TOTAL		151

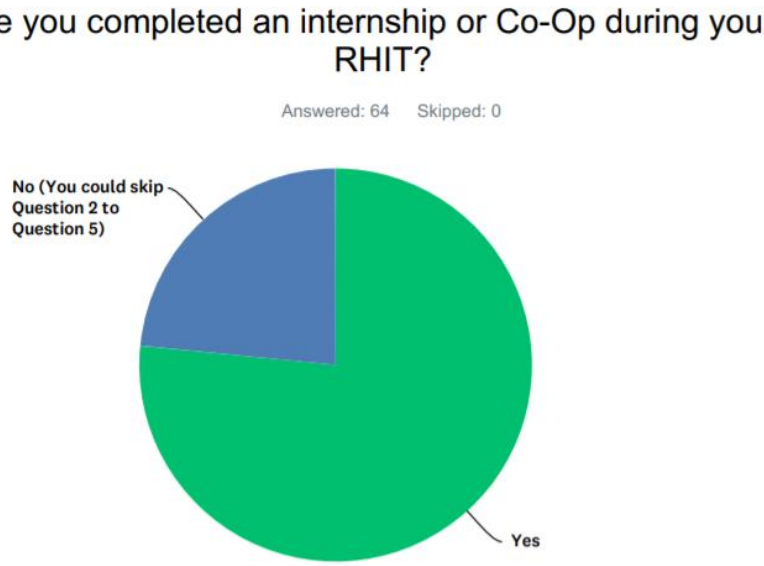
Figure C5. Summary of Question 5 responses



ANSWER CHOICES	RESPONSES	
Yes	76.87%	113
No	23.13%	34
TOTAL		147

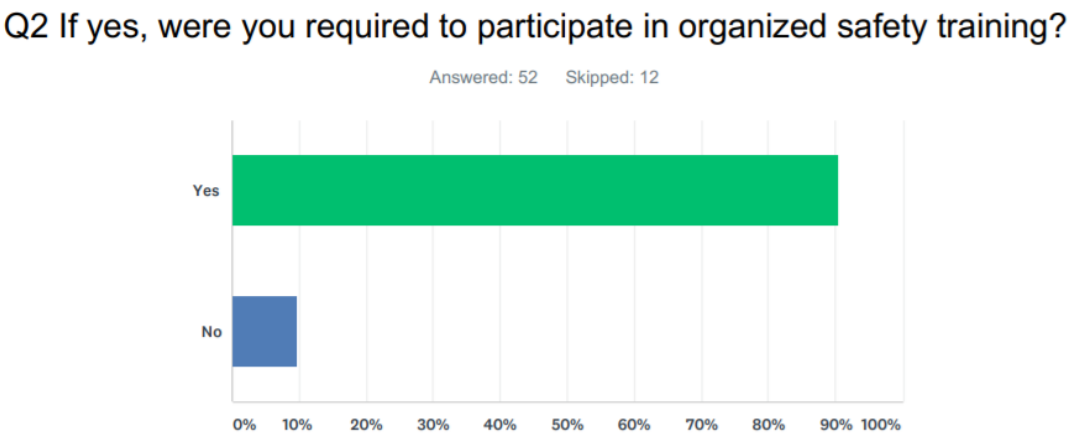
Figure C6. Summary of Question 6 responses

Appendix D. Summary of ChE UO Lab Survey



ANSWER CHOICES	RESPONSES	
Yes	76.56%	49
No (You could skip Question 2 to Question 5)	23.44%	15
TOTAL		64

Figure D1. Summary of Question 1 responses

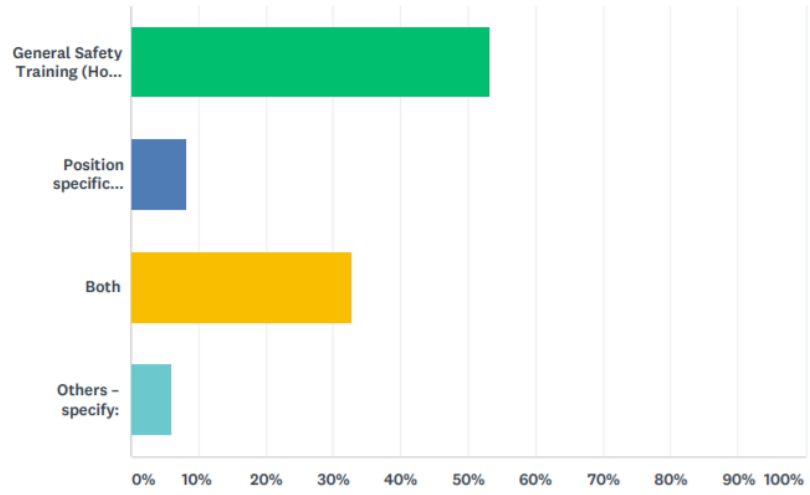


ANSWER CHOICES	RESPONSES	
Yes	90.38%	47
No	9.62%	5
TOTAL		52

Figure D2. Summary of Question 2 responses

Q3 If yes, what type of safety training you have had?

Answered: 49 Skipped: 15



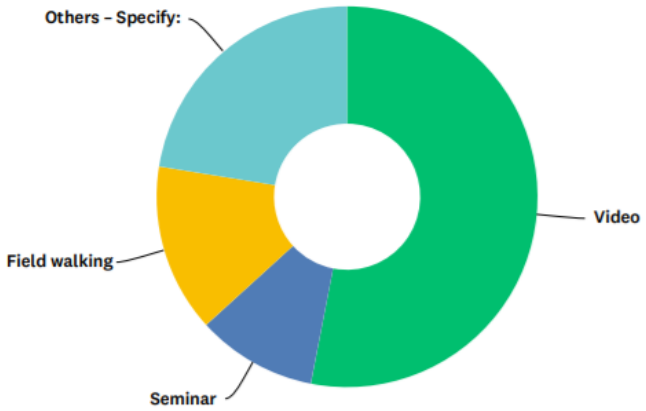
ANSWER CHOICES	RESPONSES	
General Safety Training (Hot Work, Confined Space, Evacuation, etc.)	53.06%	26
Position specific training	8.16%	4
Both	32.65%	16
Others – specify:	6.12%	3
TOTAL		49

#	OTHERS – SPECIFY:	DATE
1	nothing	1/17/2018 1:39 PM
2	Everyone that enters the plant is required to have some general safety training. I also attended an Arc Flash Safety training course. The plant held safety training sessions once a month for specific areas of concern.	1/16/2018 1:46 PM
3	none	12/7/2017 1:46 PM

Figure D3. Summary of Question 3 responses

Q4 What kind of instructional methods were used for the safety training?

Answered: 49 Skipped: 15



ANSWER CHOICES	RESPONSES	
Video	53.06%	26
Seminar	10.20%	5
Field walking	14.29%	7
Others – Specify:	22.45%	11
TOTAL		49

#	OTHERS – SPECIFY:	DATE
1	A mix of all the above	1/17/2018 1:39 PM
2	Video, PowerPoint, Field Walking	1/16/2018 1:43 PM
3	All of the above	1/16/2018 1:40 PM
4	Video, seminar, and field walking	1/16/2018 1:40 PM
5	The guy in charge of safety just talked to us.	1/16/2018 1:39 PM
6	Video and Field Walking	1/16/2018 1:39 PM
7	There were online modules as well as classroom sessions.	12/7/2017 4:11 PM
8	All of the above	12/7/2017 1:52 PM
9	none	12/7/2017 1:46 PM
10	All of the above and many more	12/5/2017 1:25 PM
11	Video and seminar, but these werent checkboxes so I couldnt select both	12/4/2017 2:58 PM

Figure D4. Summary of Question 4 responses

Q5 Please note if you remember something impressive about the safety trainings.

Answered: 33 Skipped: 31

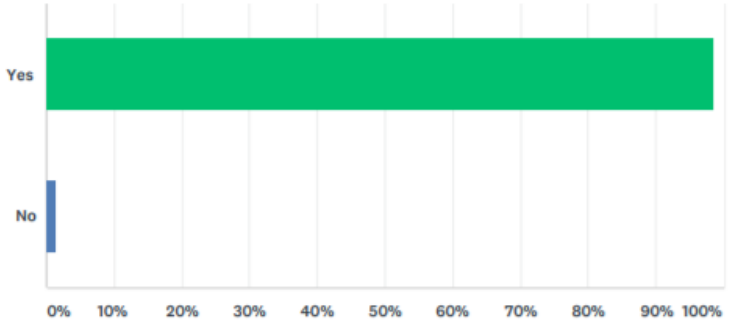
#	RESPONSES	DATE
1	mainly talked about detailed safety regulations. like, for specific work, the worker must get permission from the specific department before entering the working area	1/17/2018 1:49 PM
2	AICHE safety boot camp	1/17/2018 1:42 PM
3	I worked in a lab so they went ahead and demonstrated all of the safety techniques in use at the facility.	1/17/2018 1:42 PM
4	examples	1/17/2018 1:40 PM
5	Safety was very much stressed and they said you were accountable for your safety and the safety of others	1/17/2018 1:39 PM
6	no	1/17/2018 1:39 PM
7	Nothing impressive about those safety meetings	1/17/2018 1:38 PM
8	Just the real life examples of the consequences of not following safety rules.	1/17/2018 1:37 PM
9	Repeated stressing of "safety first"—if somethings SEEMS unsafe, it likely IS.	1/16/2018 1:52 PM
10	N/A	1/16/2018 1:46 PM
11	There was an exam after all the safety training, earning less than 80% would result in redoing the whole safety training	1/16/2018 1:43 PM
12	I dont remember them at all what is safety	1/16/2018 1:43 PM
13	Statistics that highlight dangers and injuries resonate with me	1/16/2018 1:43 PM
14	The safety training was very thorough and included things that I never would have thought I needed to know but they were very useful.	1/16/2018 1:40 PM
15	N/A	1/16/2018 1:40 PM
16	Extensive. Some of them were interesting such as air respirators. Some were more boring, such as those on video.	1/16/2018 1:40 PM
17	Many of the videos were repetitive.	1/16/2018 1:40 PM
18	They were very in-depth and the general training covered almost every aspect of the lab work	1/16/2018 1:40 PM
19	if you see something say something	1/16/2018 1:39 PM
20	N/A	1/16/2018 1:39 PM
21	Informative	1/16/2018 1:38 PM
22	All employees were serious about safety and multiple visuals in the plant such as colored lines specifying when hearing protection was needed and signs saying how long you can stay out in the plant according to the temperature made safety even more clear	12/7/2017 4:41 PM
23	The classroom sessions involved a thorough walk-through of all possible hazards associated as well as a field walk.	12/7/2017 4:11 PM
24	Safety adviser took the role very seriously	12/7/2017 1:59 PM
25	I remember learning about the different types of fire extinguishers and what their specific uses are.	12/7/2017 1:52 PM
26	none	12/7/2017 1:46 PM
27	N/A	12/7/2017 1:39 PM
28	N/A	12/5/2017 1:45 PM

29	We had "safety bucks" which people received for having safety conversations and finding things to fix. These could be used to buy various prizes.	12/5/2017 1:25 PM
30	Nope	12/4/2017 9:18 PM
31	The large threat that somethings contained.	12/4/2017 2:37 PM
32	They talked and had a lot of videos that were showing the worst things that could happen if you did not follow the safety rules and procedures.	12/4/2017 12:06 PM
33	Nothing in particular	12/4/2017 10:51 AM

Figure D5. Summary of Question 5 responses

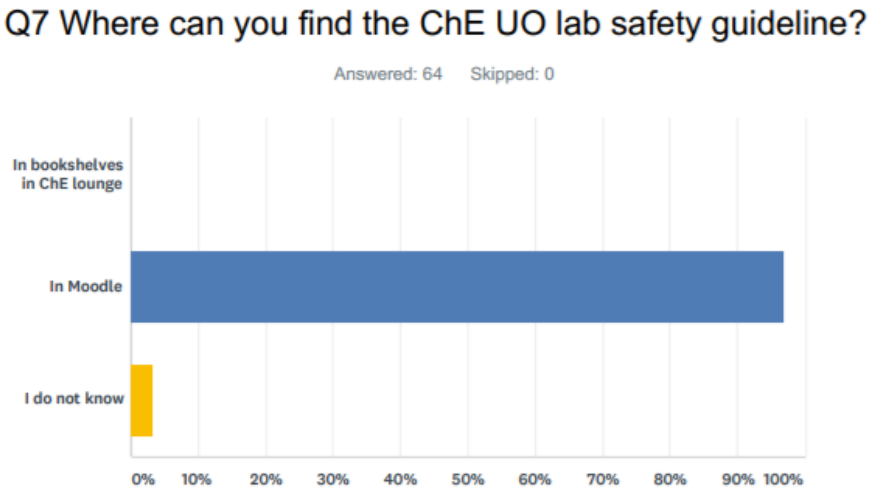
Q6 Does the Chemical Engineering Department have safety guidelines for the ChE UO laboratory?

Answered: 64 Skipped: 0



ANSWER CHOICES	RESPONSES	
Yes	98.44%	63
No	1.56%	1
TOTAL		64

Figure D6. Summary of Question 6 responses

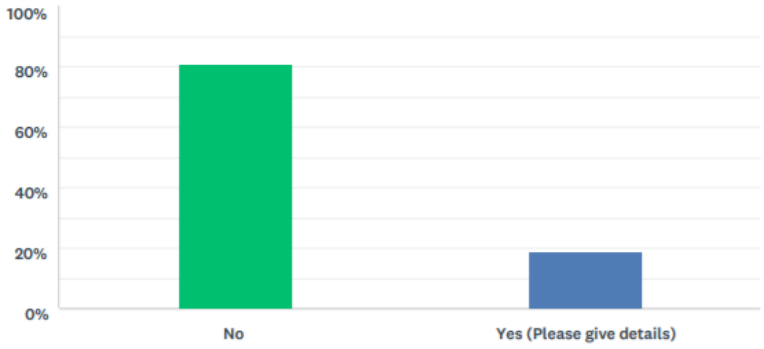


ANSWER CHOICES	RESPONSES	
In bookshelves in ChE lounge	0.00%	0
In Moodle	96.88%	62
I do not know	3.13%	2
TOTAL		64

Figure D7. Summary of Question 7 responses

Q8 Have you experienced any hazardous situations/items in the ChE UO laboratory?

Answered: 63 Skipped: 1



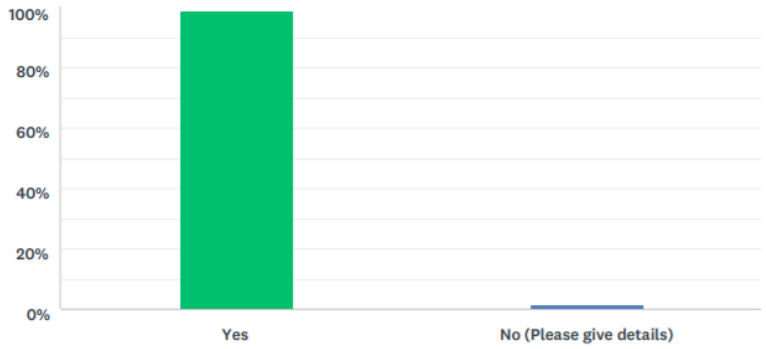
ANSWER CHOICES	RESPONSES	
No	80.95%	51
Yes (Please give details)	19.05%	12
TOTAL		63

#	YES (PLEASE GIVE DETAILS)	DATE
1	our group left the system without people there for 1 min	1/17/2018 1:49 PM
2	The Filter press project is very hazardous	1/17/2018 1:40 PM
3	The ladder to the second level of the high-bay lab feels somewhat unsafe without an accompanying guard surrounding it. Installing one at the upper level might be a good plan.	1/16/2018 1:52 PM
4	I believe some of the chemicals used for the tubular reactor experiment were hazardous. When handling those, special care and safety precautions were used such as wearing gloves.	1/16/2018 1:46 PM
5	During my agitated tank experiment, the steam came out from somewhere once, which was super scary.	1/16/2018 1:43 PM
6	N/A	1/16/2018 1:42 PM
7	I hit my head once	1/16/2018 1:38 PM
8	Exposed spindle on the Parr reactor	12/7/2017 4:28 PM
9	ethyl acetate	12/7/2017 1:52 PM
10	The whole place has tons of metal edges that you can easily bump your head or other body parts into.	12/7/2017 1:52 PM
11	The valve for the agitated tank was too hot to use by hand so gloves were used to open that valve.	12/7/2017 1:46 PM
12	Chalk spraying everywhere, E. coli spraying everywhere, Needle pricks in the presence of E. coli, broken glass	12/4/2017 2:58 PM

Figure D8. Summary of Question 8 responses

Q9 Do you feel safe in the ChE UO laboratory?

Answered: 63 Skipped: 1



ANSWER CHOICES	RESPONSES	
Yes	98.41%	62
No (Please give details)	1.59%	1
TOTAL		63

#	NO (PLEASE GIVE DETAILS)	DATE
1	I feel like a lot of what we do is safety theater that actually creates risk. For instance, my visibility is reduced by my hardhat, so I walk into things, making the hardhat necessary to compensate for itself. I had to wear cut resistant gloves while handling needles, but the gloves were large and cumbersome, which ultimately resulted in a prick from which the gloves did not protect me. I have a severe skin condition, but was not consulted about it before being assigned to the filter press experiment, which is particularly hazardous for someone with my condition. I feel that there are severe ergonomic hazards inherent in the UO lab, in that we are working on laptops and sitting on awkward chairs or stools, often with work surfaces at awkward heights. Generally I do not feel that sufficient thought has been put into keeping me safe and healthy in UO lab. I am always uncomfortable here and I do not feel safe. I don't really feel like the department cares about keeping me safe, they just want to LOOK like they care.	12/4/2017 2:58 PM

Figure D9. Summary of Question 9 responses

Q10 Suggest two ways to improve safety in ChE UO laboratory.

Answered: 49 Skipped: 15

ANSWER CHOICES	RESPONSES	
1.	100.00%	49
2.	79.59%	39

#	1.	DATE
1	More comfortable helmets and safety glasses/goggles would increase PPE compliance - people stop wearing their equipment because .	1/17/2018 1:58 PM
2	The lockers (or at least some of them) containing the PPE could be moved upstairs to reduce traffic and time without PPE in the lab.	1/17/2018 1:42 PM
3	Train the students on how to use their equipment	1/17/2018 1:40 PM
4	print out the safety protocol and place it somewhere in the lab	1/17/2018 1:39 PM
5	More spacing between equipment to prevent tripping hazards	1/17/2018 1:39 PM
6	Encourage the student to take the online safety course from AIChE	1/17/2018 1:39 PM
7	better instruction	1/17/2018 1:39 PM
8	Have instructors discuss safety hazards more clearly with students	1/17/2018 1:38 PM
9	Exit signs on all doors that can be used as exits	1/17/2018 1:37 PM
10	Find a better way to address the drains and hoses emptying into them	1/17/2018 1:37 PM
11	Safety railing around ladders	1/16/2018 1:52 PM
12	N/A	1/16/2018 1:46 PM
13	Improve on the SOPs	1/16/2018 1:43 PM
14	Dogs	1/16/2018 1:43 PM
15	Hearing Protection more easily found - Frank just passes them out to group that are close to the pumps group.	1/16/2018 1:43 PM
16	if girls cant wear leggings boys cant wear sweatpants	1/16/2018 1:43 PM
17	Instructor Led JSA's or PHA's for each Project	1/16/2018 1:42 PM
18	Make sure cords and power strips are better taken care of.	1/16/2018 1:41 PM
19	A video training might be useful.	1/16/2018 1:40 PM
20	Post hazards at each station.	1/16/2018 1:40 PM
21	Require safety videos and tests before work on a specific project can take place.	1/16/2018 1:40 PM
22	Rather than just having students perform safety analysis on their area, have some kind of pre-written guide as well.	1/16/2018 1:40 PM
23	evaluate each station for corroded surfaces or deteriorating insulation that might expose students to unforeseen injuries	1/16/2018 1:40 PM
24	make sure every SOP is corrected and updated	1/16/2018 1:39 PM
25	stress importance of wearing hardhats, it seems kind of pointless	1/16/2018 1:39 PM
26	Make sure that operation of the units is well understood before letting people start running the instruments.	1/16/2018 1:39 PM
27	make the safety contract an annual paper to sign	1/16/2018 1:39 PM
28	Less exposed hot pipes on heat exchanger	1/16/2018 1:39 PM

29	Its good	1/16/2018 1:39 PM
30	Make hard hats more fun	1/16/2018 1:38 PM
31	Better locker placement (possibly not in the active work area)	12/11/2017 8:34 PM
32	More space between projects to prevent clutter and tripping hazards	12/7/2017 4:41 PM
33	Remove tripping hazards near pumps/instrumentation area	12/7/2017 4:28 PM
34	Ear protection near the pumps experiment	12/7/2017 4:11 PM
35	Remove clutter	12/7/2017 2:25 PM
36	reviewing safety throughout the year	12/7/2017 1:59 PM
37	Be aware of surroundings	12/7/2017 1:52 PM
38	Actually do safety training. Don't just say "look on Moodle"	12/7/2017 1:52 PM
39	Posting a video on moodle for how to correctly operate each lab would be useful	12/7/2017 1:46 PM
40	Lab Shadowing for lower classmen	12/7/2017 1:39 PM
41	There are many tripping hazards from spacial issues and many tubes near the ground that could be cleared more efficiently.	12/5/2017 4:23 PM
42	make sure to refresh peoples memory for each segment	12/5/2017 1:45 PM
43	Exposed spindle on par reactor	12/4/2017 9:18 PM
44	Pay attention to ergonomic risks. Provide better work surfaces. (For instance, desks you can put your knees under in lab areas, so that you are not precariously hunched over a laptop for 8 hours a week. Provide better seats. pay attention to other potential occupational hazards. Provide hearing protection.	12/4/2017 2:58 PM
45	Have exit signs on doors that can be used as exits.	12/4/2017 2:37 PM
46	maybe some sort of drill to practice the safety plans that are in place	12/4/2017 2:22 PM
47	Reduce the number of exposed wires	12/4/2017 2:05 PM
48	Make students wear earplugs when the pumps project is running.	12/4/2017 12:06 PM
49	an overview of all UOs in CHE411 would allow you to identify safety concerns related to adjacent projects you may otherwise know nothing about	12/4/2017 11:00 AM

#	2.	DATE
1	Remind students to keep liquid waste containers closed unless actively pouring out waste.	1/17/2018 1:58 PM
2	I can't really think of anything else right now, it's a pretty safe environment.	1/17/2018 1:42 PM
3	Have a safety list for startup and shutdown for all projects	1/17/2018 1:40 PM
4	emphasize the hazardous situations more	1/17/2018 1:39 PM
5	Share the potential safety hazard that the instructor have experienced before to remind students of the importance of safety culture	1/17/2018 1:39 PM
6	more time	1/17/2018 1:39 PM
7	Have students go through a formal training in the use of the equipment with the instructor at first to make sure they are running the equipment properly.	1/17/2018 1:38 PM
8	If the noise in the lab is loud enough in areas, hearing protection should be required rather than optional	1/17/2018 1:37 PM
9	Move the lockers upstairs so PPE is worn at ALL times in the UO lab	1/17/2018 1:37 PM
10	Provide gloves for Filter Press experiment to prevent pinching fingers in plates	1/16/2018 1:52 PM
11	Provide lab aprons when needed	1/16/2018 1:43 PM
12	More dogs	1/16/2018 1:43 PM
13	Better organize shelves in lab rooms. Glassware is scattered, doesn't have a "home" and sometimes sits close to the edge of counter tops.	1/16/2018 1:43 PM

14	gloves required when handling steam valves	1/16/2018 1:43 PM
15	N/A	1/16/2018 1:42 PM
16	Put insulation on hot equipment.	1/16/2018 1:41 PM
17	A handout with safety expectations before lab starts i.e. clothing specifications, what projects need glasses versus goggles	1/16/2018 1:40 PM
18	Safety test.	1/16/2018 1:40 PM
19	Wear ear protection at all times. Everywhere I worked we were required to wear it, even in areas where there was not that much noise.	1/16/2018 1:40 PM
20	Require boots instead of leather shoes	1/16/2018 1:40 PM
21	put some kind of heat protection on the agitated tank steam valve	1/16/2018 1:39 PM
22	Be sure to keep it up to date when new experiments are added	1/16/2018 1:39 PM
23	More organized drug delivery lab	1/16/2018 1:39 PM
24	Hearing protection at least for short periods of time when a project can be loud, such as starting up or shutting down	12/7/2017 4:41 PM
25	Make filter press less messy	12/7/2017 4:28 PM
26	N/A	12/7/2017 4:11 PM
27	Spread UOs out more	12/7/2017 1:52 PM
28	Seriously, actually have safety training. (should take entire 1st day)	12/7/2017 1:52 PM
29	A lot of the labs do not have a lot of free space so reducing the clutter at some of the labs would be helpful.	12/7/2017 1:46 PM
30	Intro to UO class	12/7/2017 1:39 PM
31	Some of the areas are too crowded for proper movement in the low bay are and, in the case of the emergency, could be difficult to evacuate from.	12/5/2017 4:23 PM
32	keep the same safety guidelines we have now	12/5/2017 1:45 PM
33	Open electric wiring on RO setup	12/4/2017 9:18 PM
34	You NEED to take a medical survey of students prior to assigning lab projects. You need to know if they are asthmatic, and if so, don't put them into high risk situations for asthmatics (i.e. high dust, high humidity). You need to know if they have a weakened epidermis, which can make the chalk in the filter press experiment extremely painful to touch, even in small concentrations, which happens even when extreme care is taken. You definitely should not put someone with severe asthma and severe eczema on the freaking filter press. Medical survey. Do it. Please do it.	12/4/2017 2:58 PM
35	Provide a more in depth general training session before the first day of lab rather than just wear your hard hat and safety boots.	12/4/2017 2:37 PM
36	more discussion of the individual safety hazards of each project	12/4/2017 2:22 PM
37	Record guidelines for required safety equipment for EACH unit operation	12/4/2017 2:05 PM
38	Move the lockers upstairs so that students are wearing PPE before they get to the laboratory.	12/4/2017 12:06 PM
39	automatic kill switches for certain projects; never been on a project that needed one, but some of them might	12/4/2017 11:00 AM

Figure D10. Summary of Question 10 responses