

Keeping the Memory Alive, Preventing Memory Loss That Contributes to Process Safety Events

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Acronym listing

HSE – Health, Safety and Environment

LOPC – Loss of Primary Containment

MOC – Management of Change

PJHA – Pre-Job Hazard Assessment

PSE – Process Safety Event

RCA – Root Cause Analysis

Abstract

Recurring process safety events (PSEs) are a real concern to the energy industry. Contributing causes to these events are quite often very similar. It appears as though the learnings from past events are not retained in the memories of the workforce, setting the stage for accidents to repeat. Even with best practices available to prevent such recurring accidents, these events continue to happen again and again. It seems as if something is missing, in order to effectively use the knowledge gained from so many past disasters and near misses, to prevent further PSEs.

It was desired to develop a tool to aid ConocoPhillips Canada (CPC) in preventing memory loss that is contributing to PSEs. Some of the world's worst process safety accidents were reviewed to gather common learnings, and investigation reports of CPC past PSEs were analyzed to determine how prevalent the issue of memory loss is within the company. Best practices to prevent such memory loss were researched and found to be readily available, and yet for some reason, memory loss issues are very widespread. The cognitive sciences were looked to for an answer on how memories are developed and effectively retained. The field of education was researched, to determine how leading educators effectively teach learning to achieve high levels of memory retention. Through this taxonomy table, a tool which has been used by educators to enhance teaching and learning for many years, was discovered. Then, effective safety communication methods that target memory retention were explored. All researched information was finally tied together, into a learning curriculum, consisting of various activities. These activities were constructed to advance the learning process towards an objective that had been carefully developed using the taxonomy table guidelines. This objective was 'for the workers to integrate past process safety learnings to prevent future process safety events.'

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1. Introduction

Far too many PSEs occur in the energy industry that could be easily prevented. According to Gerstein (Ref 6, px), organizations continually fail to learn from past errors and disasters, allowing accidents to repeat across industry and even with the same companies. Renowned process safety expert Trevor Kletz refers to many process safety accidents that he investigated, where he could have simply pulled a list of contributing causes from the files of previous accidents already investigated but forgotten by many. (Ref 8, p1) And Mannan (Ref 12, chap27, p18) states that the memory within an organization that should help to prevent process safety accidents decays thus allowing accidents to repeat.

To determine if the same concerns hold true for CPC, a review was undertaken of past PSEs. The company has a rigorous incident investigation program in place and yet still encounters recurring PSEs. A detailed review of these past investigations was undertaken, to gain an understanding of the type of events that have been occurring and if memory loss has played a role. It was then determined, through an interview process involving several key company individuals, that the memory of past PSEs was waning, especially after approximately three years. After three years, the events seemed to be all but forgotten unless there had been a personal involvement with the event.

Industry has been learning from PSEs for many years, and many best practices are available to help remember lessons learned. There are many safety experts working hard to implement these best practices, and yet accidents repeat, with very similar contributing causes, for both industry and CPC. Even with best practices in place, memory loss continues to contribute to PSEs.

In an attempt to determine why memories of these past events seem to diminish so quickly, the cognitive sciences were explored to better understand how memories are developed and retained. This led to an understanding of techniques that help to establish memories with better retention, such as original awareness, and developing triggers within the memory for future recall. Research on memory retention led to various methods of communication that can enhance the ability for a memory to be retained. It was learned that, in general, safety messages are not communicated in an effective manner to enable memory retention.

Now understanding the problem at hand, a solution was sought that would help to teach lessons of the past in a manner that allows for effective memory retention, and through this the ability to improve process safety. The field of education was researched for best practices that enable learning. A taxonomy for learning, teaching, and assessing has been developed by experts in the field of education, and employed for many years to help advance learning needs. This taxonomy was explored further to determine how it could be used to help CPC enhance memory retention and process safety.

Learnings from industry, CPC, best practices, the cognitive sciences, and effective communication were incorporated into a learning curriculum within this taxonomy tool. The resulting activities are designed to develop required knowledge through specific cognitive actions. Key components of these activities are:

- One page drawing overview summaries of past process safety events

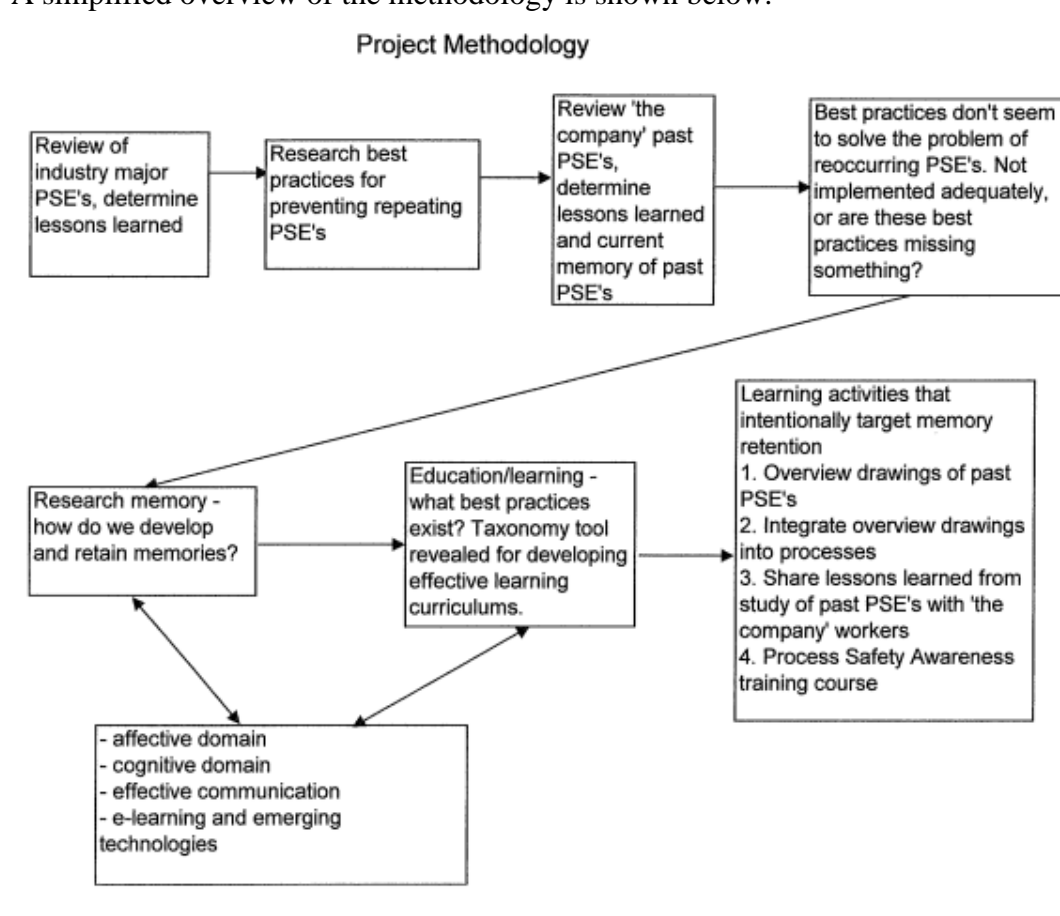
- Combine learnings of past events from industry and CPC into process safety awareness training

In summary, not adequately learning from lessons of past PSEs has proven to be a critical issue that hampers organizations within the energy industry. The problem is not that we don't know what causes these accidents, but that we do not effectively teach the lessons learned in a manner that allows the memory to be retained within the organization. The objective of these activities is to do just that— to teach lessons learned so that the knowledge is stored effectively in the memory and is able to be retrieved when it will aid in preventing PSEs.

2. Project Methodology

To determine tools or a technique to enable an energy company to “keep the memory alive” and not forget the lessons learned from past PSEs, the first step is to understand the problem at hand. Then one can move forward with developing a method to solve the problem. This method has to be carefully developed, looking at how others have attempted to solve the problem, and what may be missing from the ‘formula’ that others have utilized. The new method then needs to be implemented, with opportunities to assess its effectiveness and adjust technique as required to continually improve the process. This section describes the methodology used to gain an understanding of the problem and then develop the solution.

A simplified overview of the methodology is shown below.



It was first desired to gain an understanding of the problem of memory loss as it relates to the energy industry. Research looked at various significant PSEs that occurred throughout the industry in all areas of the world. Particular importance was paid to large disasters that had numerous fatalities or significant impact to the surrounding community. Many of these disasters led to changing regulations in the industry. A high-level look at common contributing causes and accidents with recurring contributing causes was undertaken. Lessons learned were gathered for comparison between these industry disasters.

Best practices, as portrayed by leading process safety experts and organizations, were then researched. Before attempting to fix a problem, it is advantageous to understand how other experts have attempted to solve the problem in the past. Materials from renowned process safety expert Trevor Kletz, *Perry's Chemical Engineers' Handbook*, and additional information available from the Center for Chemical Process Safety were researched, specifically for best practices to enable an organization to retain memory of past PSEs.

CPC was then assessed to determine how memory loss may be contributing to PSEs. It was determined to analyze past PSEs, consisting of both accidents and near-misses, as these near-misses only needed circumstances to change ever so slightly to alter the course from near-miss to PSE. This information would then be used in an attempt to assess the level of memory, within CPC, of past PSEs. This information indicated there was potentially a memory problem contributing to PSEs, but more information was still required to confirm this. It was determined that an interview process would be needed to further assess this, and several key individuals were a part of this past PSE review. Analyzing results of interviews showed there was a definite lack of memory relating to past PSEs, similar to what research indicates throughout the industry. Known best practices seemed to tell us what we ought to do to improve memory, and yet, past lessons are forgotten resulting in recurring process safety events. It seemed as if something was missing; how to effectively remember and learn from the past.

It was not known how to solve this dilemma, and so the cognitive sciences were explored for an answer. Research into how the brain functions, how memory works and how humans learn was carried out, hoping that knowledge in this field would lead to a solution that would in essence help to improve memory of the past and thus reduce process safety events. This research did lead to some best practices in memory retention, and also to the study of effective teaching and learning. The educators have been researching methods for effective teaching and learning for many years and are considered leaders in this area. It was desired to learn what some best practices are for teaching, learning and assessing, and how to build learning activities into the development of a tool or technique to improve how CPC can best learn to keep the memory of the past alive and in everyday use. Through discussion with leaders in the field of learning, the taxonomy tool, an aid used by educators to develop learning curriculums since 1956, was researched.

Methods of communication to aid in effectively delivering the material to be taught and remembered were also researched, that would complement available knowledge on how the memory works and how humans learn. This led to determining methods for effectively displaying written and pictorial communication that can vastly improve memory retention. Improvements that can be gained through the use of various forms of e-learning were researched, and the outcome is very promising. There is almost unlimited potential in this field but, at this time, data is lacking to substantiate the potential benefits. It needs to be pursued, albeit cautiously, because the usage is increasing across the world so rapidly. Best practices for developing and structuring learning courses to enable memory retention were researched. All this information was utilized, with the taxonomy tool, to develop a learning curriculum for 'the company'. An objective was first created, that was "Students should learn to integrate past process safety learnings to prevent future PSEs". The learning curriculum, comprised of activities that were designed to achieve this objective, was then developed. The lessons learned

from past industry accidents, industry best practices, learnings from CPC RCAs and interviews, and knowledge gained from memory and communication research were all taken into account to build activities that would achieve the objective.

3. Results

3.1 Energy Industry Review of Past PSEs

The energy industry has long been struggling to prevent the recurrence of process safety accidents. An overview look at some of the past significant accidents shows some alarming trends in common contributing factors, and an inability to learn from the past. Incidents reviewed included Piper Alpha, Longford, Texas City, Flixborough, Bhopal, Mexico City, Pasadena, and others. Results of this work aligned with a report by Derek Park, of *Oil and Gas IQ*, entitled Never Say Never Again. (Ref 14, p1) Park refers to the relevance of a famous warning quoted by George Santyana that “Those who cannot remember the past are condemned to repeat it.” The report details how this warning has been unheeded by the energy industry, exemplified by various past accidents.

So the question is asked, “Why can’t industry learn from significant accidents in different organizations, and why do we have to see recurring accidents, so similar and with the same contributing causes?” Trevor Kletz, discusses this in his book, *Lessons From Disaster, How Organizations Have no Memory and Accidents Recur.* But he also discusses how serious accidents repeat in the same organization, given time, as memory of an accident fades.

3.2 Industry Best Practices to Help Remember the Past

The energy industry has learned a lot from accidents of the past. In fact, Kletz states: “It is not the lack of knowledge that prevents our safety record being better than it is, but a failure to use the knowledge that is available, much of it acquired as the result of past accidents.” (Ref 8, p96) And yet, the industry continues to have accidents with common contributing causes. So what is the knowledge that is available from the experts in the process safety field – what are best practices that, if followed, should help to prevent these recurring accidents?

Perry’s Chemical Engineer’s Handbook, a world-famous reference for the process safety industry, reiterates what Kletz states, saying that we know how to prevent most accidents, but they occur because we do not utilize the information that is available to us. Over time, the recommendations made following an accident are forgotten, procedures are allowed to lapse, changes are made to equipment and the accident is just waiting to happen again. (Ref 15, p26-7)

Looking specifically at a very significant process safety accident that occurred at Longford, Victoria, Australia in 1998, where an explosion at the facility killed two workers and the city of Melbourne lost its gas supply for a two week period. One of the key findings of the investigation was that Esso’s various failures were due to ‘an absence of mindfulness.’ Study of high reliability organizations, such as nuclear, aerospace and airline, show that organizations within these industries are always mindful of the possibility of disaster. This culture allows them to never ‘put their guard down’ but always to be on the lookout for the precursors to a disaster. (Ref

7, p7) Because of this lack of mindfulness at Esso, the organization did not actively search within for warning signs of pending accidents, or look outside of itself for lessons that could be learned from other organizations in the industry. (Ref 7, p9) This thinking led the organization to believe that, prior to the Longford explosion, they were competent and skillful in the area of process safety simply because they had not suffered disasters in the past. This then led to justification to reduce effort and redundancy in this area. This type of culture within an organization leads to the result that ‘current success makes future success less probable.’ (Ref 7, p141) It is very important for a company to have a healthy sense of vulnerability, to believe that something that hasn’t yet caused a problem can still be a dire incident in the making. (Ref 3, p5,8) Organizations need to be open to risk and the possibility that failure can occur to them. Being risk-blind is at the root of most tragedies. (Ref 6, p64)

3.3 *Review of CPC Past PSEs*

The investigation reports for eighty-four PSEs were reviewed.

The data reviewed gave a strong indication that memory loss is playing a role in recurring contributing causes and process safety events. It does not, however, show specifically where this is contributing to PSEs. How can the company have such a repeat of contributing factors leading to recurring PSEs, if the organization were truly remembering the past PSEs? Something seemed amiss and the answer was thought to perhaps lie within the workers. As Kletz has stated, “Organizations do not learn from the past or, rather, individuals learn but they leave the organization, taking their knowledge with them, and the organization as a whole forgets.” (Ref 8, p1) Plans were then made to attempt to determine the level of memory of workers. Interviews were carried out to help determine how prevalent memory loss is with regards to process safety events that have occurred at CPC.

Interviewees were well aware of all events within the last three years. Beyond three years, interviewees were unaware of the event unless one of three reasons existed:

- They had been in their current role and thus personally involved in the event and the recommendations that ensued.
- The event was of such significance that it resulted in substantial changes within the business.
- A recent event, either with CPC or with a peer company, had created discussion and triggered someone’s memory of the past event

It is concerning that these three reasons that enable memory do not in themselves represent methods that enable memory retention very far into the future. The first – personal involvement, will pass when the individual retires or moves into a different position. The second – event significance to the company, will wane as time progresses, and several interviewees expressed this exact concern. And the third reason – event recently remembered due to a similar failure, is exactly what this study is attempting to solve, events repeating because the past has been forgotten.

3.4 *So What’s Missing?*

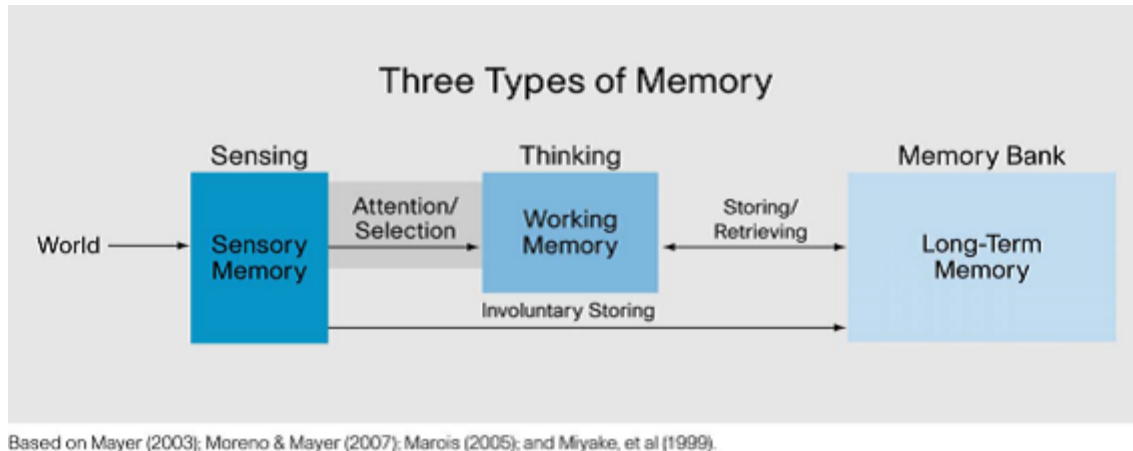
Thus far we have review of industry literature showing that there are various best practices available to prevent process safety events, and yet significant accidents still occur, often with contributing causes that are repeated, or not learned, from other significant process safety accidents. The review of CPC RCAs shows a similar trend, and the subsequent interviews with various key personnel has proven that there is a problem with memory of past process safety events. It is not, however, based on the fact that nothing has been done in an attempt to remember the past events. In many instances, good investigations have been done, bulletins issued, training implemented and recommendations carried out. It seems then, that what has been done to remember lessons learned has been ineffective in transferring this knowledge and keeping the memory alive.

Best practices from various references highlight many different methods that will aid in remembering lessons learned from previous accidents. One such practice is simply stated - to not forget about the old accidents, and review them from time to time. This does not, however, address the importance of how the communication of these events benefits with the use of memory retention techniques. Without an intentional method to effectively deliver the lessons learned in a manner that yields optimal retention, individuals will quickly forget and the learnings will not be built into improvements within the organization. This only leads to repeating the contributing causes that will continue to lead to further similar process safety events. This is one very important aspect of learning from past events that seems to have been missed by industry and CPC.

3.5 *Memory*

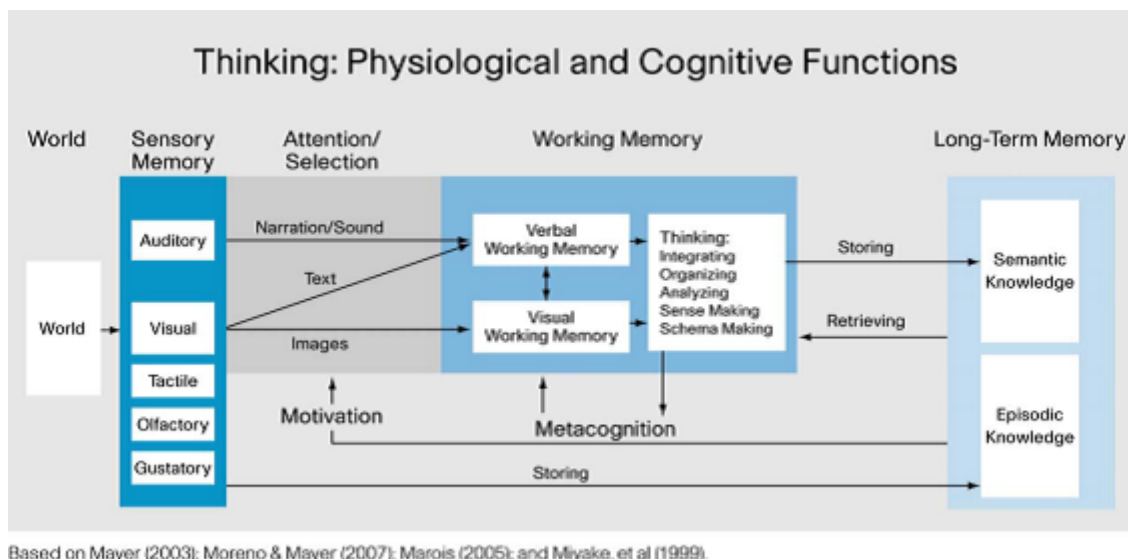
Memory is defined as “the faculty of recalling or recognizing previous experiences” or “the length of time over which remembrance reaches.” (Ref 16) So the questions are asked: “What makes a memory?” “What makes a memory stick in an individual’s mind?” “What makes a memory stick within an organization?” Memory expert Harry Lorayne, in *The Memory Book*, explains that people often claim to forget something, when in fact they never actually remembered it in the first place. The problem is that people do not become “originally aware” of the information, or create an association in their mind that allows the information to be effectively remembered. (Ref 11, p6) Information needs to make its way into long-term memory to be effectively stored for retrieval at a later date. (Ref 4) Long-term memory is one of three types of memory that people are equipped with, the others being sensory memory and working memory. (Ref 5, p24) Understanding how the brain functions through utilization of these different memory types may be an important piece to implementing effective memory retention and recall of process safety learnings, and was thus explored further.

A simplistic depiction of these three memory types is shown below:



Sensory memory is enacted when triggers from the outside world are captured through the human senses. They are stored in sensory memory involuntarily and can transfer from here into either working memory, if they are thought about, or into long-term memory, if not thought about. Working memory, as indicated by its name, is where the brain does the thinking, although it is limited by capacity. Memories are only in the working memory while being thought about, and then proceed into long-term memory. Long-term memory has essentially unlimited storage capacity, and works in parallel with the working memory. The working memory retrieves memories from the long-term memory as needed and available. (Ref 5, p9)

Further detail of the thought processes within the brain:



The working memory has two different components to it: the verbal working memory, and the visual working memory. The verbal working memory includes inputs such as noises, conversations, and writings. The visual working memory includes inputs such as drawings, pictures, and physical movements. The working memory buffers and processes these two

different input sources separately, and these two information streams work together to build understanding. The working memory is very much limited by its capacity, as researchers believe that the verbal working memory has a capacity of seven objects, while at the same time the visual working memory is limited to approximately four objects. According to Sweller, cited in *Cisco*, (Ref 5, p9) cognitive overload can result from either of these buffers being overfilled. However, if verbal and visual working memories are successfully utilized together in creating a memory, there are more triggers in place to recall this memory, and any of these triggers will help to recall this entire memory. (Ref 5, p10)

The sensory memory takes in any aspect of the world captured through the human senses. If the mind pays attention to this sensory memory, it then transfers into working memory. If no special attention is paid to the sensory memory, it then moves into long-term memory as episodic knowledge. (Ref 5, p10) Episodic knowledge tends to degrade quickly. The other type, known as semantic knowledge, arises from knowledge that passes through the working memory into long-term memory. This knowledge has much better retention than the episodic knowledge, due to the links or triggers created in working memory that allow it to be pulled back from long-term memory when needed. (Ref 5, p10)

3.6 Learning

According to Bransford, cited in *Cisco*, research into the cognitive sciences of how people best learn reveals three important methods that enhance learning: (Ref 5, p11)

1. Learning is improved when existing knowledge is built upon to create new concepts.
2. Learning is improved when the learning topic has a direct personal meaning to them.
3. Learning is improved when students are forced to use existing knowledge to learn from failures and attempt to predict outcomes.

The study of cognitive sciences then led to research in the field of education or more specifically, the discipline of teaching and the subsequent learning that is desired as a result of teaching efforts. Bloom's taxonomy is a tool used by educators throughout the world. Since its inception in 1956, it has been referred to as one of the leading methods to influence education, both in America and the world. (Ref 1, pxx1) A revision to the 1956 B.S. Bloom's (editor) *The Taxonomy of Educational Objectives, The Classification of Educational Goals, Handbook I: Cognitive Domain* has been recently published, entitled *Abridged Edition, A Taxonomy for Learning, Teaching, and Assessing, A Revision of Bloom's Taxonomy of Educational Objectives (2001)*. This edition incorporates new knowledge that has influenced the education process since the writing of the Bloom's original text. (Ref 1, pxxII)

The taxonomy is an educational aid that follows a defined process. It utilizes the taxonomy table, (Table 1) that lays out the interrelationships between the cognitive and knowledge dimensions. This process helps teachers set objectives and then model or plan their training in a manner that facilitates achievement of the objective. Instruction should then be intentional and set out to achieve the objective. (Ref 1, p3)

The objective is first developed that contains a specific verb and noun. The verb, which describes the intended cognitive process, is chosen using the Cognitive Process Dimension table. (Table 2)

A noun, that describes the knowledge that is expected to be acquired by the students, is chosen and fit to the Knowledge Dimension Table. (Table 3) At this point the objective statement is created. (Ref 1, p4) The objective is then placed on the taxonomy table, at the intersecting point of the cognitive and knowledge dimensions.

Table 1: (Ref 1, p28. Reprinted by permission of Pearson Education, Inc., Upper Saddle River, New Jersey)

The Knowledge Dimension	The Cognitive Process Dimension					
	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge						
Conceptual Knowledge						
Procedural Knowledge						
Meta-cognitive Knowledge						

Table 1: The Revised Taxonomy Table

The objective statement is paramount as it is the foundation for the process, which then builds around the desired outcome. It describes the intended result that is wanted to be achieved. It does not describe the means to attain the end result. (Ref 1, p17) This is instead attained through learning activities. These activities are developed, that will help achieve the objective, and are added to the taxonomy table, at the appropriate location that depicts the knowledge and cognitive attributes of each activity.

It is very important that the ‘affective domain’ is targeted as a component of the learning activity. The affective domain is the category of learning where one develops attitude and motivation. As this is developed, the student better receives the knowledge and becomes motivated to respond to it. This can even lead to creation of a personal value to the learning and, in turn, enhanced commitment. As this affective domain advances, learning in the cognitive domain improves as the student desires to learn more. Increased learning in the cognitive domain then further develops the affective domain. In this manner, the two domains complement each other, leading to enhanced learning and retention. (Ref 5, p1,4)

According to Anderson and Krathwohl, effective use of the taxonomy table can help educators in at least three ways:

1. Focused attention on objectives leads to a deeper understanding of the learning question.
2. Taking this deeper understanding of objectives and then applying the thought process to determine how the objective fits to the taxonomy table, calculating both the knowledge and cognitive dimension of the objective, leads to better decisions on instruction and assessment of the student’s attainment of the objective.
3. Help determine how well the objectives, instructional activities, and assessment can complement each other. (Ref 1, p95)

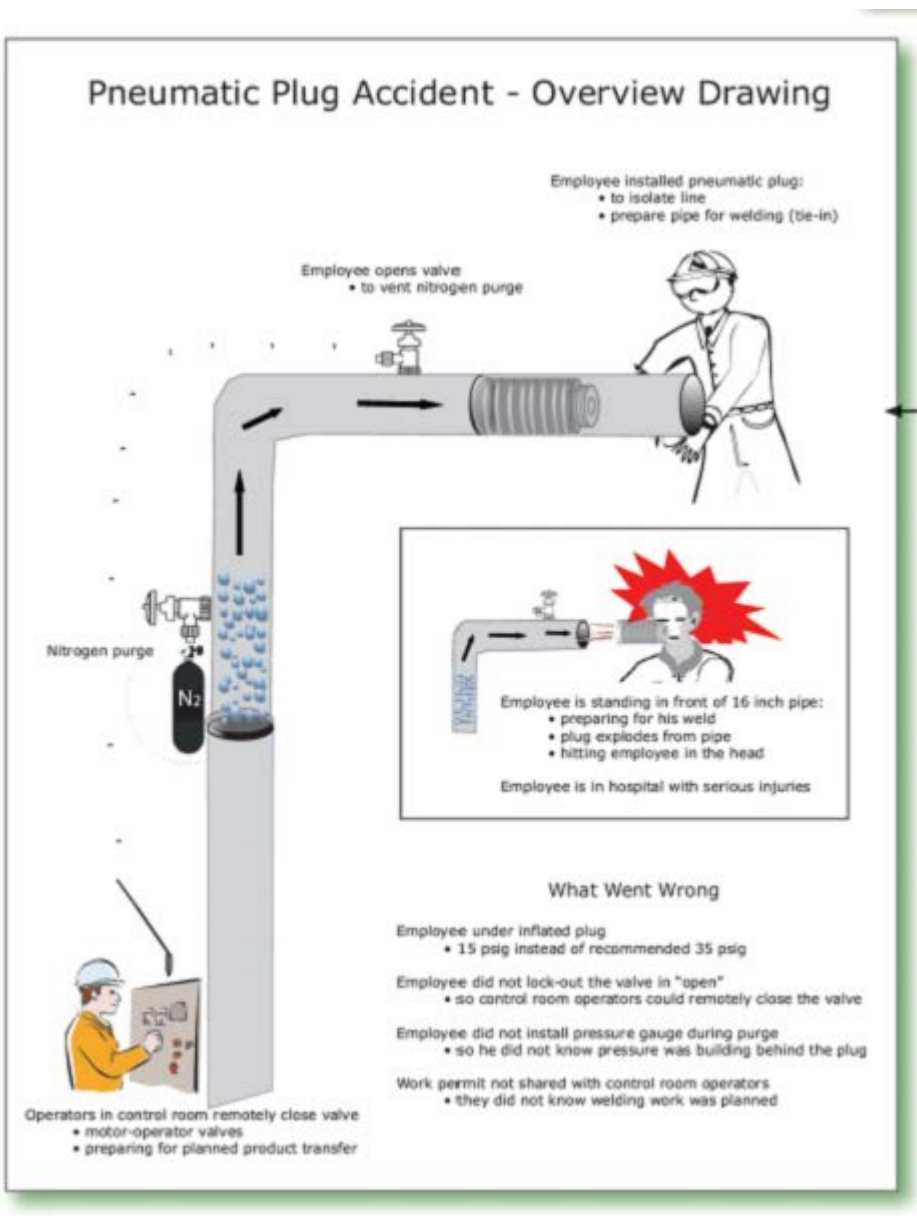
When the process is performed effectively, it should lead to memory retention and then allow for the student to use what was learned to solve new problems – effectively linking past learnings to future improvements. (Ref 1, p63)

Learning begins with thoughtful preparation of the message to be taught, and then effectively communicating this message. Dr. TJ Larkin, of Larkin Communication Consulting, is an expert on communication and further specializes in safety communication. According to Larkin, industry has done a poor job of effectively communicating safety messages to the workforce. Some of the key errors that have been made include:

- Providing too much information. According to O'Reilly, cited in Larkin (Ref 10, p3), there is a point where too much information leads to poorer performance.
- Information is presented at too high a grade level for the audience to comprehend. According to Aldridge and Brownson, cited in Larkin (Ref 10, p5), the average reading level of U.S. adults is 7th grade. And Larkin (Ref 10, p5), citing DuBay notes that safety communication at oil refineries nears a 16th grade level, while a grade level of 5 to 7 should be targeted to achieve what is considered effective communication.
- Words and pictures are poorly organized, yielding a safety message that is inadequately presented. Pictures should be simple, even hand-drawn, to capture the main points that need to be communicated. Utilizing a simple hand-drawn drawing to represent a complex event can increase comprehension by as much as 600 percent. (Ref 9, p8)

Effective safety communication should have three layers – simple picture, simple text, and technical information that is separate but available for those who desire or need to delve deeper into the subject. (Ref 9, p8) Diagram 1 shows an example drawing that is designed with simple picture and simple text.

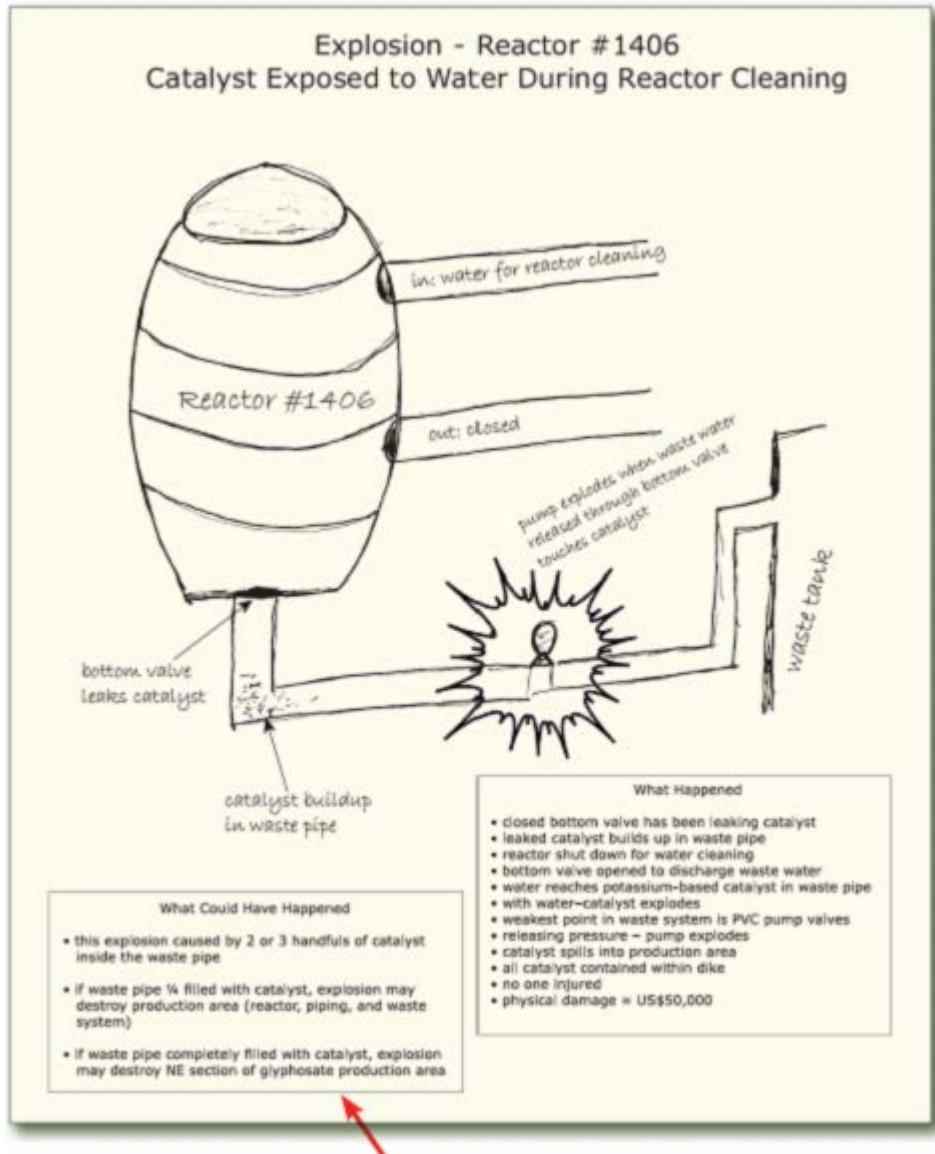
Diagram 1 Overview Drawing of Incident (Ref 9, p8 with permission)



Another communication method that can assist in making a memory stick is to utilize speculation in the review of an incident. According to Morris, cited in Larkin (Ref 9, p9), speculating about

“what could have happened” as opposed to a “facts only” approach can enhance learning by 70 percent. Diagram 2 shows a sample drawing that includes speculation.

Diagram 2 Overview Drawing Showing Speculation (Ref 9, p9 with permission)



Chunking is also an effective learning strategy. Chunking is a term that was formulated by Harvard psychologist George A. Miller in 1956. It revolves around the belief that smaller bits of information taken in by the working memory allow it to process information in an optimal manner, enabling an easier integration into the long-term memory. The Research Institute of America has found that memory retention increases significantly when the chunking concept is applied. (Ref 2). Larkin’s simple drawings build around the chunking concept in the manner in which incident information is presented. This is seen in Diagrams 1 and 2, with information grouped into small bits around the page.

3.7 *Applying The Taxonomy Table to CPC*

Effective use of the taxonomy table should allow for an intentional learning curriculum to be built for CPC to help prevent memory loss that contributes to PSEs. The goal is to build learning activities within the taxonomy table, utilizing the knowledge gained thus far from:

- Research into major industry accidents.
- Learnings from CPC RCAs.
- Industry best practices.
- Memory retention techniques.
- Emerging e-learning technologies.
- Effective communication methods that target affective and cognitive domains.

The learning activities are designed to achieve an objective that is carefully constructed and placed within the taxonomy table. The objective statement is comprised of a verb and a noun. First, the noun was determined to be ‘past process safety learnings’. This refers to remembering past PSEs from CPC, their potential impact on workers, the contributing causes relating to the various types of RCAs the company has encountered, and the lessons learned pertaining to the underlying root, or latent causes. It is also important to utilize the experiences from past industry accidents, so those same lessons do not have to be learned ‘the hard way’.

Then a verb is chosen, from the Cognitive Process Dimension Table (Table 2). This table lists and describes nineteen specific cognitive processes. From this table, under the category of ‘Analyze’, the verb ‘integrating’ has a strong fit with the desired intent. The definition of integrating is: “Determining how elements fit or function within a structure” and the example given is “structure evidence in a historical description into evidence for and against a particular historical explanation.” These descriptors fit well with the intent of this study – “determining how elements fit or function within a structure” aligns with determining how previous RCAs fit into a workers role and how various process safety hazards fit into the larger operation of the company. The example “structure evidence in a historical description into evidence for and against a particular historical explanation,” fits into the process safety events and how they can have an impact on process safety in the future. More simply stated, it is the desire to have workers able to analyze events that have occurred in the past to make improvements in the future.

Table 2 (Ref 1, p. 67, 68. Reprinted by permission of Pearson Education, Inc., Upper Saddle River, New Jersey)

The Cognitive Process Dimension		
CATEGORIES & COGNITIVE PROCESSES	ALTERNATIVE NAMES	DEFINITIONS AND EXAMPLES
1. REMEMBER—Retrieve relevant knowledge from long-term memory		
1.1 RECOGNIZING	Identifying	Locating knowledge in long-term memory that is consistent with presented material (e.g., Recognize the dates of important events in United States history)
1.2 RECALLING	Retrieving	Retrieving relevant knowledge from long-term memory (e.g., Recall the dates of important events in United States history)
2. UNDERSTAND—Construct meaning from instructional messages, including oral, written, and graphic communication		
2.1 INTERPRETING	Clarifying, paraphrasing, representing, translating	Changing from one form of representation (e.g., numerical) to another (e.g., verbal) (e.g., Paraphrase important speeches and documents)
2.2 EXEMPLIFYING	Illustrating, instantiating	Finding a specific example or illustration of a concept or principle (e.g., Give examples of various artistic painting styles)
2.3 CLASSIFYING	Categorizing, subsuming	Determining that something belongs to a category (e.g., Classify observed or described cases of mental disorders)
2.4 SUMMARIZING	Abstracting, generalizing	Abstracting a general theme or major point(s) (e.g., Write a short summary of events portrayed on a videotape)
2.5 INFERRING	Concluding, extrapolating, interpolating, predicting	Drawing a logical conclusion from presented information (e.g., In learning a foreign language, infer grammatical principles from examples)
2.6 COMPARING	Contrasting, mapping, matching	Detecting correspondences between two ideas, objects, and the like (e.g., Compare historical events to contemporary situations)
2.7 EXPLAINING	Constructing models	Constructing a cause-and-effect model of a system (e.g., Explain the causes of important 18th Century events in France)
3. APPLY—Carry out or use a procedure in a given situation		
3.1 EXECUTING	Carrying out	Applying a procedure to a familiar task (e.g., Divide one whole number by another whole number, both with multiple digits)
3.2 IMPLEMENTING	Using	Applying a procedure to an unfamiliar task (e.g., Use Newton's Second Law in situations in which it is appropriate)

4. ANALYZE—Break material into its constituent parts and determine how the parts relate to one another and to an overall structure or purpose		
4.1 DIFFERENTIATING	Discriminating, distinguishing, focusing, selecting	Distinguishing relevant from irrelevant parts or important from unimportant parts of presented material (e.g., Distinguish between relevant and irrelevant numbers in a mathematical word problem)
4.2 ORGANIZING	Finding coherence, integrating, outlining, parsing, structuring	Determining how elements fit or function within a structure (e.g., Structure evidence in a historical description into evidence for and against a particular historical explanation)
4.3 ATTRIBUTING	Deconstructing	Determine a point of view, bias, values, or intent underlying presented material (e.g., Determine the point of view of the author of an essay in terms of his or her political perspective)
5. EVALUATE—Make judgments based on criteria and standards		
5.1 CHECKING	Coordinating, detecting, monitoring, testing	Detecting inconsistencies or fallacies within a process or product; determining whether a process or product has internal consistency; detecting the effectiveness of a procedure as it is being implemented (e.g., Determine if a scientist's conclusions follow from observed data)
5.2 CRITIQUING	Judging	Detecting inconsistencies between a product and external criteria, determining whether a product has external consistency; detecting the appropriateness of a procedure for a given problem (e.g., Judge which of two methods is the best way to solve a given problem)
6. CREATE - Put elements together to form a coherent or functional whole; reorganize elements into a new pattern or structure		
6.1 GENERATING	Hypothesizing	Coming up with alternative hypotheses based on criteria (e.g., Generate hypotheses to account for an observed phenomenon)
6.2 PLANNING	Designing	Devising a procedure for accomplishing some task (e.g., Plan a research paper on a given historical topic)
6.3 PRODUCING	Constructing	Inventing a product (e.g., Build habitats for a specific purpose)

The objective is to have workers take past process safety learnings and integrate this knowledge into the situations encountered in the workplace to prevent future PSEs. So an objective is created; “Students should learn to integrate past process safety learnings to prevent future PSEs.” And it is now examined against the Knowledge Dimension (Table 3) to see where it should be placed on the Taxonomy table.

Table 3 (Ref 1, p.46. Reprinted by permission of Pearson Education, Inc., Upper Saddle River, New Jersey)

The Knowledge Dimension

MAJOR TYPES AND SUBTYPES	EXAMPLES
A. FACTUAL KNOWLEDGE—The basic elements students must know to be acquainted with a discipline or solve problems in it	
AA. Knowledge of terminology	Technical vocabulary, musical symbols
AB. Knowledge of specific details and elements	Major natural resources, reliable sources of information
B. CONCEPTUAL KNOWLEDGE—The interrelationships among the basic elements within a larger structure that enable them to function together	
BA. Knowledge of classifications and categories	Periods of geological time, forms of business ownership
BB. Knowledge of principles and generalizations	Pythagorean theorem, law of supply and demand
BC. Knowledge of theories, models, and structures	Theory of evolution, structure of Congress
C. PROCEDURAL KNOWLEDGE—How to do something, methods and inquiry, and criteria for using skills, algorithms, techniques, and methods	
CA. Knowledge of subject-specific skills and algorithms	Skills used in painting with watercolors, whole-number division algorithm
CB. Knowledge of subject-specific techniques and methods	Interviewing techniques, scientific method
CC. Knowledge of criteria for determining when to use appropriate procedures	Criteria used to determine when to apply a procedure involving Newton's second law, criteria used to judge the feasibility of using a particular method to estimate business costs
D. METACOGNITIVE KNOWLEDGE—Knowledge of cognition in general as well as awareness and knowledge of one's own cognition	
DA. Strategic knowledge	Knowledge of outlining as a means of capturing the structure of a unit of subject matter in a textbook, knowledge of the use of heuristics
DB. Knowledge about cognitive tasks, including appropriate contextual and conditional	Knowledge of the types of tests particular teachers administer,

knowledge	knowledge of the cognitive demands of different tasks
DC. Self-knowledge	Knowledge that critiquing essays is a personal strength, whereas writing essays is a personal weakness; awareness of one's own knowledge level

First comparing the descriptors for Conceptual and Factual Knowledge, it was determined that the objective had a stronger link to Conceptual Knowledge, as it is important for various workers to understand the underlying causes of the PSEs that have occurred, and not just remember the facts of the events. This aligns with the general statement for conceptual knowledge: “the interrelationships among the basic elements within a larger structure that enable them to function together” (from Table 3.) The subtype from this table that aligns with the objective knowledge is “knowledge of classifications and categories.” There is great value if knowledge attained by the workers enables them to understand the different type of PSEs, process safety hazards and contributing causes, and are able to classify and categorize these, then integrate this knowledge into various tasks and situations they encounter. In some instances, the desired knowledge falls within the Procedural Knowledge type. This knowledge type was assessed and compared to Conceptual Knowledge, but it was determined that in most cases the worker needs to understand the situation and potential hazard, and use this knowledge to determine how to best prevent the process safety hazard from becoming a PSE, rather than attain procedural knowledge to apply to the situation at hand.

In summary then, the objective is that “Students should learn to integrate past process safety experiences to prevent future PSEs,” and this is placed on the taxonomy table intersecting “Analyze” and “Conceptual Knowledge”.

The end result now is preventing future PSEs which is really the true desire. The process of determining an objective and how it fits within the taxonomy framework yields an increased understanding of what needs to be attained (Ref 1, p5), this statement proven by the careful analysis and development of objective statement within this report.

Now that an objective is created, it is imperative to develop a learning curriculum that is appropriately designed to achieve the objective. The stated objective can be seen to be in cell 4B of the CPC taxonomy table. (Table 4)

It was observed through the interview process, and discussions with various operators, that there is a lack of knowledge, or memory, of past RCA investigations and events that have occurred. This lack of factual knowledge reflects the current state of the organization, and spotting this current state on the taxonomy table positions this current state at 1A – deficient in memory of factual knowledge. This is the initial state, the starting point for the learning activities, which now need to be developed to progress the company from here to the objective in cell 4B. Knowledge needs to advance from factual to conceptual, while cognitive skills will need to be

developed to remember, followed by understand, then apply and finally allow the student to analyze conceptual knowledge.

Table 4 CPC Learning Activities Within the Taxonomy Table

	The Cognitive Process Dimension					
The Knowledge Dimension	1. Remember	2. Understand	3. Apply	4. Analyze	5. Evaluate	6. Create
A. Factual Knowledge	Activity 1: Intended to help students recognize past PSEs and store in long term memory for effective retrieval	Activity 2: Intended to help students understand how past PSEs specific to their job function have developed	Activity 3: Intended to help students implement their understanding of contributing factors.			
B. Conceptual Knowledge		Activity 4: Intended to help students understand the underlying causes of PSEs.		Objective: Students should learn to integrate past process safety learnings to prevent future PSEs		
C. Procedural Knowledge						
D. Meta-Cognitive Knowledge						

3.8 *Learning Activities*

Learning activities need to be successful to attain the objective. They need to be designed to enhance memory retention, but the success of learning activities is also strongly linked to how effectively the affective domain is tapped into. The affective domain is known to consist of attitude and motivation. According to Edwards and Porter, cited in Miller (Ref 13, p1), “a student’s attitude toward a given course or subject area can be a contributing factor to his achievement in it.” The ensuing learning activities are designed to grow attitude in the student, increasing the motivation to want to learn and subsequently increase memory retention. Miller, citing Simonson and Maushak (Ref 13, p6) highlights six guidelines that support increasing attitude through instruction. These are quoted here, with comments specific to how these apply to the learning activities developed for CPC, in parentheses:

- “Make the instruction realistic, relevant, and technically stimulating.” (Have learning activities comprised of real scenarios, graphically stimulating, relevant to their job, intended to pique interest)
- “Present new information.” (Even though utilizing past PSEs, these are new to most. Present the information in a non-typical manner that catches the students attention)
- “Present persuasive messages in a credible manner.” (Showing the impact of what has or can really happen to them, in a short, to the point persuasive manner)
- “Elicit purposeful emotional involvement.” (Stressing what bad things can really happen to them, appealing to the student’s sense of emotion, and what can be done to prevent it)
- “Involve the learner in planning, production or delivery of the message.” (The interview process was used to query what was felt the effectiveness of Larkin’s overview drawings would be – all queried felt they would be very effective. These drawings are being further enhanced to target the affective domain. Workers that were personally involved in past PSEs were enlisted to ensure the portrayal is accurate and meaningful to others)
- “Provide post-instruction discussion or critique opportunities.” (This will be done post-learning activities as part of review and adjust process)

The students should have an inherent motivation to learn as much as possible about past PSEs, because of the personal significance these events can have on them. Still, the affective domain needs to be intentionally targeted with the learning curriculum.

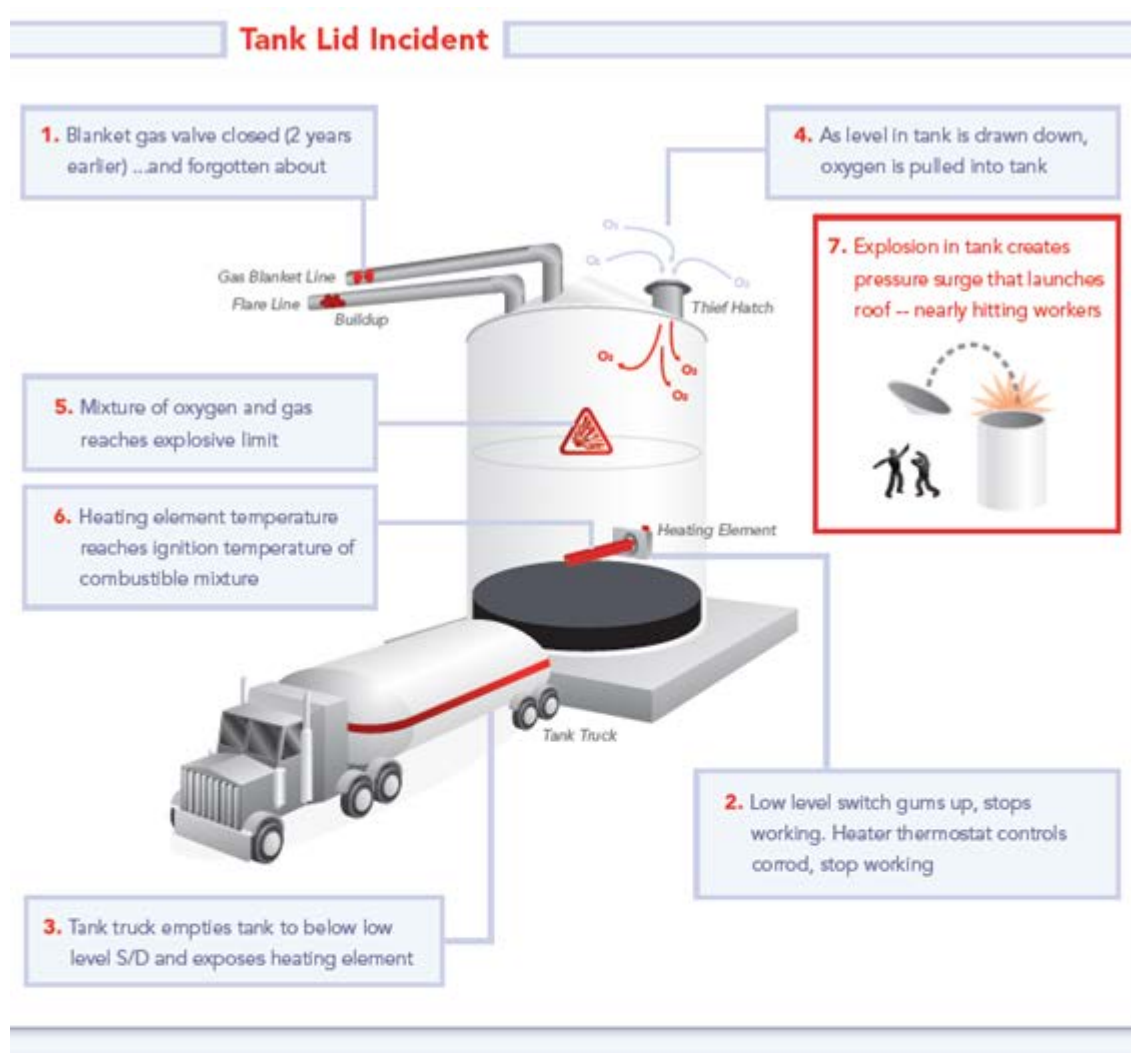
Activity 1 - The first learning activity needs to address the initial concern, that past RCA investigations seem to be unknown to the workforce and, if known at the leadership level, are only retained in memory for a short time unless personally involved at the time of the event. This activity should draw on the knowledge gained from research of effective communication, memory retention and best practices within the industry. The aim at cell 1A is to remember factual knowledge – in this case it can be stated that that the intent is to recognize past PSEs and store in long-term memory for effective retrieval. According to Anderson, (from Table 2), recognizing involves being able to pull relevant information from long-term memory to compare it with current information. Industry best practices highlight the importance of reviewing past PSEs, keeping the memory of these alive and sharing with new employees. Larkin suggests a one page overview drawing that summarizes an incident (Diagram 1.) This is good in that it is organized in chunks, is written simplistically, and utilizes both verbal and visual memories in a manner that forces information presented to pass through the working memory, creating more

triggers to allow for recall at a later date when needed. It focuses attention on to the specifics of the incident in a manner that creates an original awareness, and should help to elucidate the hazards associated with the event.

Now, specifically targeting the affective domain can even further enhance memory retention. It is desired to motivate the student, to appeal to his attitude and therefore develop an inherent 'want' to learn the lessons that are available to be learned from the past PSEs. To achieve this, an education company specializing in e-learning was enlisted, to reach out to the affective domain of students. Diagram 3 and Diagram 4 are simplified portrayals of past PSEs at CPC. The three-dimensional enhancement and inclusion of speculating: "What else could have happened?" should appeal to the affective domain. Then, as the affective domain becomes more engaged, the cognitive domain improves the memory retention.

Drawings such as these are now to be developed for many past process safety events. Various methods of delivery will be utilized to improve usage and retention. Review at Health, Safety and Environment (HSE) meetings, email messaging to mobile phones, as well as postings to HSE web page for increased accessibility of the workforce will all be utilized. The key is to bring back review of old incidents, in a manner that allows the memory to stick in the minds of the workers and to be able to be recalled for comparison to current information workers may be faced with (in working memory) as process safety hazards are encountered. In summary, Activity 1 teaches what has happened, in a manner set out to be remembered.

Diagram 3 - Tank Lid Incident - Final Overview Drawing



! What Happened

Blanket gas valve closed:

- Wasn't re-opened at end of initial job
- Site personnel never became aware of closed valve

Maintenance practices did not detect:

- Gummed up low level switch
- Corroded heater thermostat controls

Communication with trucking company did not address:

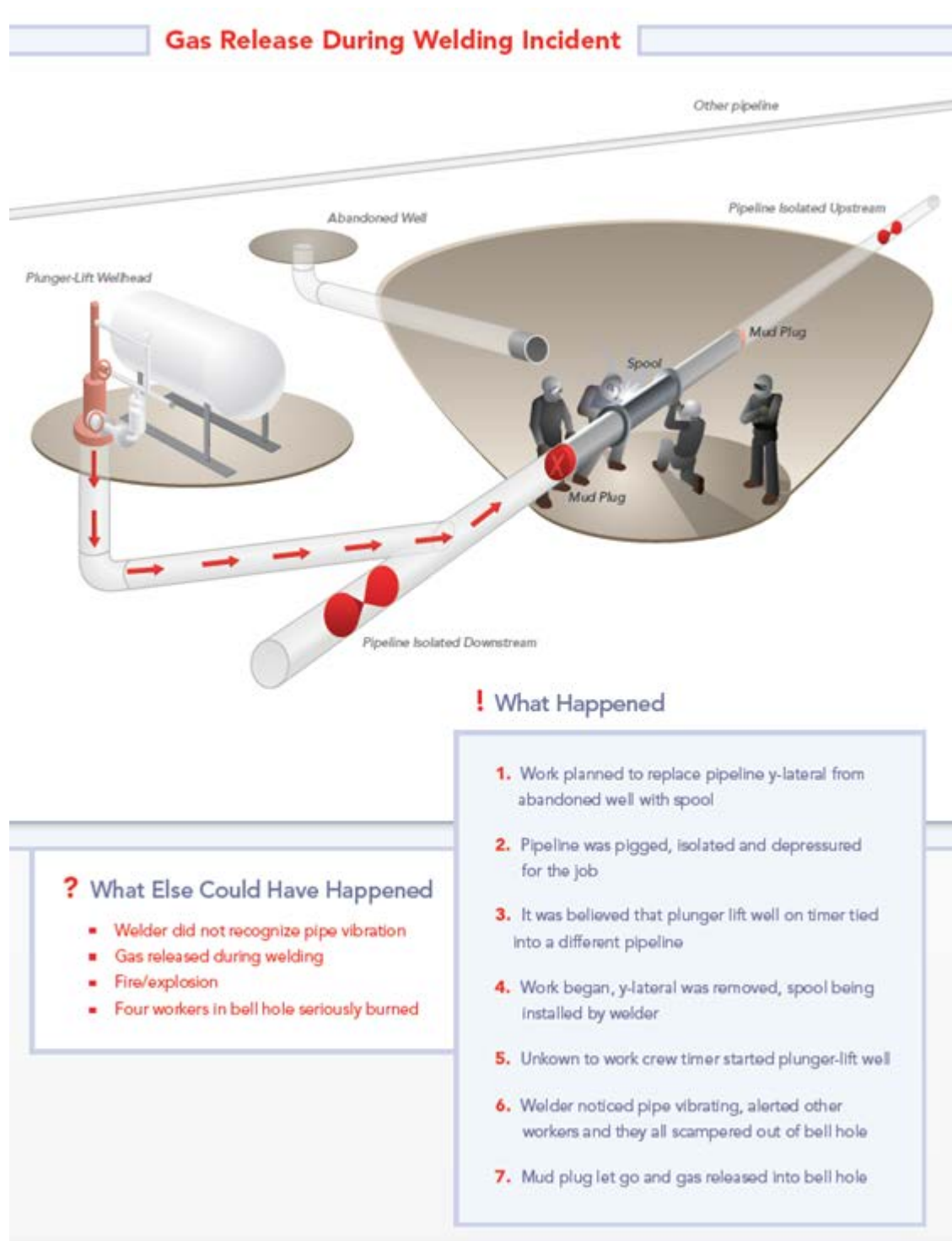
- Site alarms for low tank level
- Hazards of loading from tank with heater

? What Else Could Have Happened

Over time, the presence of oxygen led to a buildup of crud and blockage of the flare line. This could have led to:

- A similar explosion event under different operational conditions releasing large amounts of sour gas
- Thief hatch relieving sour gas leading to personnel knocked down

Diagram 4 - Gas Release During Welding Incident - Final Overview Drawing



Activity 2 – Activity 1 is the starting point to get the facts into long term memory for future retrieval when needed. The cognitive ability gained from Activity 1 itself is not sufficient to drive significant improvement in reducing recurring PSEs. To advance knowledge towards the objective, “Students should learn to integrate past process safety learnings to prevent future PSEs”, requires the memory to advance from remembering information to having the ability to make sense of this information to solve new problems. The learning needs to advance to meaningful learning, where the knowledge gained is used to solve problems. (Ref 1, p64) This learning activity falls within cell 2A, understanding factual knowledge. It is intended to help students understand how past PSEs, specific to their job function, have developed. It has been shown that students often solve problems by comparing a present situation to a past situation, and applying the solution of the past to the current state. (Ref 1, p65) Activity 2 drives towards this, by integrating the overview drawings into various processes within CPC. Some examples of how this may be accomplished are now described.

The Construction Inspector group has an on-boarding process for new inspectors, where all new inspectors go through an in-house training program. Through discussions with the supervisor for this group they are planning on utilizing the overview drawings that are applicable to their work within this on-boarding process. In this way, the past PSE is reviewed, and discussion regarding the contributing factors and prevention methods should allow the student to understand the factual knowledge of the event. Diagram 4 is an example that can be implemented. The Inspector will then be well-aware of a PSE that has occurred in the past, and, in the event he is working on a pipeline abandonment project, he can apply the solution of the past to the current state. Also the Abandonment and Operations groups can create a link to this drawing within their Management of Change process, ensuring this PSE is reviewed prior to similar work being done.

Another method of integrating the overview drawings into a process is to link an overview drawing specific to a maintenance activity into an electronic maintenance generation system. Then, when the personnel responsible for the work are preparing for the job, they will review the PSE that has occurred in the past under similar circumstances, talk through the hazards, and determine what they may need to do to prevent a similar event from occurring.

One other example would be to link an overview drawing to a safe operating procedure, and in this way include review of a past PSE related to similar work as part of the procedure review.

Activity 2 should lead the students to understand factual knowledge as the PSEs are integrated into various processes. To summarize Activity 2, it teaches what to prevent.

In essence, Activities 1 and 2 utilize the same tool, the overview drawings, but Activity 2 implements them within a process. Activity 1 is introducing the students to the various PSEs through the summary drawing reports, while Activity 2 involves a deeper understanding as the students are now developing classifications and understanding the different contributing causes.

These activities build on the three important methods that enhance learning, and were referenced in section 3.6. (Ref 5, p11)

1. Learning is improved when existing knowledge is built upon to create new concepts. (The activities 1 and 2 are building on the workers existing knowledge of the process.)
2. Learning is improved when the learning topic has a direct personal meaning to them. (The activities 1 and 2 show the workers how past events have impacted others just like them, in situations they have or will encounter. They have appealed to the affective domain.)
3. Learning is improved when students are forced to use existing knowledge to learn from failures and attempt to predict outcomes. (The activities 1 and 2 build on prior knowledge and past failures, speculating forces the workers to predict outcomes.)

Activity 3 – This activity should now lead to applying the factual knowledge gained. It involves helping the students understand that they have the tools available to prevent PSEs, and implement their understanding of the contributing factors as part of this prevention. A summary course outlining the learnings from a study of the company and industry PSEs, as well as information gathered from the interviews is to be developed. This will focus on the top process safety hazards that have contributed to PSEs at CPC and the key prevention techniques available to the workforce.

The course will be built around the following information:

A. Top process safety hazards that have contributed to CPC PSEs (in no particular order) and lessons learned:

1. Pipeline Strikes.
2. Liquids that can freeze and expand in your pressure equipment.
3. Atmospheric tanks and overpressure events.
4. Pressure Relief Valve and blowdown piping subject to reactionary forces at relief.
5. Pressured fittings and attachments.
6. Preparation of equipment for maintenance.
7. Operation of Pig traps.
8. Plunger lifts.
9. Hydrates.
10. Water Hammer.

B. Key prevention techniques

1. Procedures.
2. Hazard Recognition.
3. Management of Change and Pre-Startup Safety Review
4. Personal Safety Involvement.
5. Learning from the past.
6. Sense of vulnerability.

Activity 3 will also utilize the key learnings to promote memory retention, including the concept of chunking, writing to a lower grade level, using both verbal and visual memory cues, etc. The training will be designed to appeal to the affective domain and to enhance memory capture. In

summary, Activity 3 teaches ways to prevent PSEs. Activity 3 also begins to transcend the student's knowledge from factual towards conceptual.

Activity 4 – The previous three activities have been dealing primarily with factual knowledge. The intent of activity 4 is to develop an understanding of conceptual knowledge, or how to think about the operation in a manner that avoids the initiation of the contributing factors in the first place. To best learn from past process safety learnings and prevent the recurrence of PSEs, a solid understanding of process safety and a culture that strives to manage the hazards is paramount. Activity 4 is designed to help the students understand what process safety is, the underlying causes that contribute to PSEs, and what each worker needs to do to help prevent incidents. Gaining an understanding of conceptual knowledge, and learning how to apply this wisdom is the aim of this activity. A process safety awareness course, strategically designed to utilize the knowledge gained regarding effective communication and memory retention will achieve this.

This activity touches on many cells within the taxonomy table, but lies primarily in cell 2B - understand conceptual knowledge. However, it should also have a means of applying conceptual knowledge. Activity 4 teaches how to avoid. This activity will be developed with assistance from a training company that can help to integrate all the knowledge gained throughout this study.

When the learning activities are added to the taxonomy table, it can be seen that there are no empty rows or columns as the process advances from initial state to the objective. This is good, as an entire row or column that is vacant may indicate an alert and other learning activities may need to be added. (Ref 1, p7)

As these four learning activities are completed it should lead to attainment of the objective, which falls in cell 4B for analyze conceptual knowledge. The objective was “Students should learn to integrate past process safety learnings to prevent future PSEs”.

As the taxonomy table was utilized to analyze the learning activities, it can be seen that the objective cannot be met with the development or utilization of only one tool, but will require several tools. This is in the form of a learning curriculum made up of different learning activities, that each helps to increase knowledge and cognitive processes to the point where the objective can be attained.

X Conclusion

Not adequately learning from lessons of past process safety events has proven to be a critical issue that hampers organizations within the energy industry. This has led to recurring process safety events that often arise from very similar contributing causes. These contributing causes are typically not new to investigators but rather a regurgitation of what was previously learned through past events.

Best practices to improve memory of process safety learnings are available, and yet the problem still exists. The question is therefore asked: “Is something missing within these suggestions for improving memory within industry, and within CPC?”

It was determined the problem is not that we don’t know what causes these accidents, but instead that the lessons learned are not taught in an effective manner that allows the memory to be retained within the organization. Lessons learned need to be taught in a way that intentionally targets memory retention. To achieve this, knowledge of how memory works needs to be combined with effective, proven communication techniques. This then should be applied in concert with proven learning methods to achieve a learning that sticks in memories of the workforce. The members of the field of education are experts in learning methods, and one tool that has proven as an effective aid is the taxonomy table. This and the methodology behind it were used to construct learning activities that built on the knowledge gained from the research of the following:

- Industry PSEs.
- CPC PSEs.
- Industry best practices regarding process safety lessons learned.
- Memory development and retention.
- Effective safety communication.

The primary learning activities developed through this process were:

1. A one page overview drawings of past process safety events.
2. Process safety awareness training, developed through the combined learnings of past events from industry and CPC.

It is imperative that these learning activities are constructed to develop both the affective and cognitive domains. Specifically, they need to target memory retention, using the knowledge gathered from research of memory and effective communication. Then, an organization must build these learning methods into processes that allow the memories to remain fresh throughout the future and effectively taught to new workers. With time, an organizational culture will be developed that is more aware of process safety and vigilant to what can be done to avert process safety events.

X+1. References (examples given to show format)

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