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"Failure is Inevitable, Injury is Preventable" - A Proposed Cognitive Model for Teaching and Training in Occupational Safety and Health.

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Abstract: Safety is a part of all jobs, and therefore all workers need to be trained on what safety is and how it can be achieved. Generally, the efficiency and effectiveness of training can be improved through the use of cognitive models such as metaphors and analogies. In safety, cognitive models such as the "Safety Pyramid", the "Safety Reverse Pyramid", "Swiss Cheese Model", …etc, have been used extensively, however the field lacks a universal and comprehensive model. A well-designed cognitive model for safety has the potential to make learning safety easy, and reduce injuries and suffering in the long term. Also, having a simple safety cognitive model may provide means to incorporate safety education at an early age. This paper proposes an integrated safety cognitive model (SCM) aiming to simplify and increase the effectiveness of safety training/education. The SCM is general and inclusive of all basic safety concepts and can be used for all jobs. This presentation includes eight original illustrations that constitute the proposed safety cognitive model. Many studies were devised during the developmental phase, and were instrumental in evolving the many versions of the SCM to its current one. Because the model kept changing the results of the developmental research cannot be conclusive, however it indicated that the SCM tends to make safety training easier for both the trainees and the trainer. Trainees preferred using a model; it helped them achieve more, understand deeper, and positively adjust their attitudes and behaviors. This presentation aims to share the model with safety professionals, gain their personal evaluations, and maybe inspire some of them to do independent evaluations of the proposed SCM.

Keywords: Safety Cognitive Model, Safety Training, Safety Education.

1. Introduction1

There is sufficient evidence to support that safety training increases workers' knowledge, helps alter unsafe behavior, and reduces injury rates (M, 2022; Fu G C. P., 2019; Gao Y, 2019; M Waehrer G, 2009; EW., 2007; PA., 2006), however efficient ways to train workers remain debatable. The poorly organized and the vast technical information and regulations makes occupational safety and health training challenging for the trainer, and for the students harder to grasp and retain. The field of occupational safety and health is also relatively new and evolving. Safety management approaches have changed since the OSHA act in 1970 (M, 2022; Fu G C. P., 2019; Bonilla-Escobar FJ, 2014; Kontogiannis T, 2017; Zanko M, 2012). Few safety management standards have been issued and some are widely accepted in the industry. These developments/standards were welcomed by safety professionals; however the basics of what safety is and how it can be achieved remain elusive for the average worker/person.

Understanding human cognitive abilities is key to successful instructional design (ID) for safety training (Angelopoulou E, 2021; N., 2014). Learning theory describes how students receive, process, and retain knowledge. Cognitive, emotional, and environmental influences, as well as prior experience, all play a part in how understanding and views are acquired or changed, and knowledge and skills are retained (N., 2014; K. I. , 2018; Johnson MK, 1987). For efficient teaching/training, it is important to adjust the materials to the memory capabilities of the learner. The difference between easy and difficult is in the capacity limitations of the working memory; the higher the demand for memorizing or recalling things, then the more difficult the task and the higher the chance for errors (N., 2014; Angelopoulou E, 2021). Hence, organizing teaching material in a cascading manner with no more than seven things at each level will make learning easier than if it is not organized. The way humans deal with memory demands that are higher than their capacity is by "chunking" (N., 2014; Gobet F, 2001). Chunking is grouping multiple things into one as per a unified category, therefore reducing the demand and making it possible to be handled through the limited capacity of the working memory. Chunking multiple things together is tricky and requires a deep understanding of the whole system. Chunks and their interrelations

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make the cognitive model, therefore it is up to experienced safety professionals to construct a cognitive model that will make learning safety easy.

Models, metaphors, and analogies are all that we have to explain abstract concepts such as “Safety”. On one hand, an integrated, simplified, and comprehensive cognitive model for safety has the potential to make learning safety easy, and on the other hand the use of a non-optimum cognitive model may lead to non-optimum understanding and unsafe behavior because of “Metaphorical Fallacy” (K. D. , 1995; E., 2015; M., 2009). It is very important for safety cognitive models to be based on deep understanding of safety engineering and the human learning processes.

This research aims to improve the efficiency of safety training, by proposing a simple and comprehensive safety cognitive model that has the potential to make learning safety easy for college students, workers, and maybe for school youths. The intended readers are inclusive of experienced safety professionals from all fields, especially those with training/teaching duties. Because of limitations on the number of pages, this presentation assumes that readers are safety professionals, and therefore explanations of safety-related information and concepts are kept minimal.

2. Safety Cognitive Model

This article proposes a cognitive model for safety to increase the clarity of concepts and make learning easy. The Safety Cognitive Model (SCM) proposed in this article does not contain new basic information; however, the uniqueness is in the way the information is organized. The SCM is comprehensive of basic concepts essential for effective safety learning and practices. It is also simple as it presents the information in three cascading layers with 3-5 pieces of information for each block, which is well-matched with the limited capacity of the working memory. This model is based on risk management principles (Amundrud Ø, 2017; Ge J, 2022; Grant E, 2018; Lyu Q, 2022) and applies to occupational safety and health, and maybe to other fields including environmental protection, security, and others.

The SCM is a three-level tree plot as shown in Figure (1). At the highest level is a single block labeled “Safety”. The second level contains two blocks with the labels “Prevention” and “Preparation”; both blocks are branched into three blocks each at the third and last level of the model. Although the structure of the model is simple, it is comprehensive. The following section will explain each of the individual blocks and their interrelations.

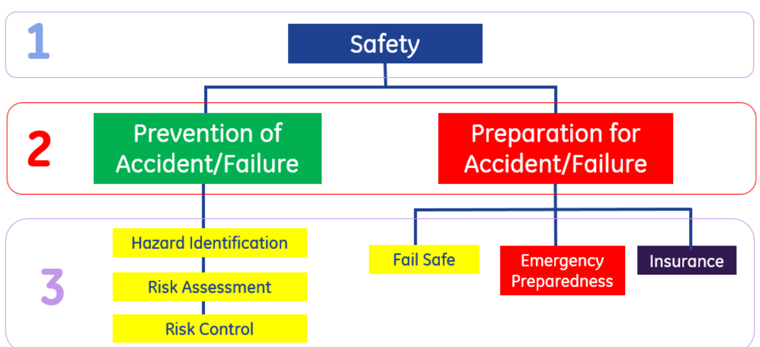

Figure 1. Safety Cognitive Model (SCM)

2.1 Level One

The “Safety” block is at the top of the model, and it represents that safety is achieved through all the branches below. In other words; to achieve safety all of the six blocks at the third level of the model should be addressed or be done. Although, the third level contains the details of what needs to be done, starting at the top level is very important to establish that “Absolute safety does not exist” and that people feel safe when the probability of bad things happening is acceptable.

In the pursuit of a definition for accidents, it is important to explain that “Accident” comes from accidental, i.e. unintentional or unplanned, however, these explanatory terms may have a regressive effect. One major common belief associated with accidents being unplanned is workers may interpret “unplanned” as “destiny” and therefore accidents are not preventable. The idea or belief that “accidents are unplanned” should be replaced by “Safety is planned”, which emphasizes that individuals and organizations have the power and the choice to be “Safe”. The term “unwanted” may be better to explain “accidental”. The second most important issue in the definition of an accident is that accidents have causes. Current definitions commonly accept that an accident results in injury, harm, and/or loss, but do not mention causes. This focus on the outcome of an accident is necessary to show importance, but there is a lack of focus on the causes. Causes may be categorized as, human error, equipment malfunction, materials, work environment, and nature-related, but they should be also collectively described as “failures”. This is linked to the previously mentioned point that “safety is planned” and therefore accidents are associated with some type of failure.

There should be a clear distinction between “injury” and “failure”. Workers’ attitude toward safety should emphasize that failure is inevitable, but injury is preventable. Such attitude encourages workers to anticipate failures and deal with it safely. Also, this distinction between “cause and effect” helps in establishing the idea that “absolute safety” does not exist. Failures are inevitable because “to err is human” and because of the “normal variation” in Nature. Therefore, failures will occur, and our safety strategy should first focus on preventing injuries by preventing failures, and secondly on dealing with failures and injuries when they happen. If causes of accidents are inevitable, bad outcomes may occur and the definition of safety becomes linked to the probability of bad things happening (Lyu Q, 2022; Fu G X. X., 2020; Gallistel CR, 2014; Ge J, 2022; Grant E, 2018; Lyu Q, 2022).

The proposed safety model is based on the following definitions: “Safety is achieved when the probability of bad things happening is acceptable”, and “An accident is an unwanted significant harm or loss caused by human error, equipment malfunction, material, adverse environment and/or nature”. This replaces the allover indistinct “accident” with a clearer safety concept of “failure causing injury”. Therefore, instead of “zero accidents” which is impossible to achieve, a more proactive slogan may be “Failure is Inevitable, Injury is Preventable”.

2.2 Level Two

Based on “absolute safety does not exist” the concepts established in level one, the strategies to achieve safety must include both prevention and preparation. Of course, an ounce of prevention is worth tons of cures, and working toward both at the same time might seem contradictory, but must be done to achieve safety.

- **Prevention of Accidents/Failures:** In this section, the goal is to prevent injuries by preventing failure. So an explicit label for this block would be “prevention of failure”.
- **Preparation for Accidents/Failures:** Preparations for failure start first by focusing on preventing the failure from causing injuries, i.e. “failing safe”. Secondly, preparations should include proper response to injuries, and dealing with the impact of the accident on the organization.

2.3 Level Three

This level includes the practical steps that have to be done to achieve safety. A good understanding of these six blocks will improve implementations of safety programs as it explains the “what’s” and “how’s” of what workers do for safety at the operational level. There are three blocks for each of the “Prevention” and “Preparation” blocks.

2.3.1 Prevention

Preventing injuries by preventing failures is achieved through three sequential steps or processes; hazard identification, risk assessment, and risk control.

A. Hazard ID: Anticipation of failures is key to achieving safety. In other words; one cannot protect him or herself from what they cannot define. Everything included in both sides of level three of the model depends on the identification of hazards. Therefore, the most important step is within the “Hazard ID” block, and identifying all hazards at work is essential for achieving safety. There are two focus points here; identifying all hazards, and fully defining each one. The discussion on how to identify all hazards at any workplace will not be discussed here, and the focus will be on fully defining a hazard, as all the following steps depend on it. Once a hazard is fully defined, all the following steps are straightforward and simple to implement. Defining a hazard requires at minimum three pieces of information and they are:

1. Safety Target or the target for protection. This is specific to a person, or a group with common activities, shared location, or other commonalities. In other words, the target is to protect the life and health of specific human/s.
2. The Source of Danger is about what could harm the safety target. It is important to link the source of danger to locations, equipment, and or activities.
3. The “Mechanism of Harm” is about how the source of danger causes harm to the safety target. It is important to classify the mechanism of harm into “chronic” or “acute”, and to identify sequential steps that lead to the occurrence of harm, as it could help in identifying specific actions that can be taken after the failure to prevent injuries.

Other information may also be included such as weather, stress, time, and or environmental factors that may affect (mainly increase) the probability and/or severity of the outcome of an accident. Accordingly, a hazard is defined as a "situation involving a source of danger with defined mechanism/s of harm that has the potential to harm a specific safety target". Identification of hazards at the workplace should be done in isolation of the impact of each hazard on the organization. The focus should be on identifying all hazards and fully defining each one, and participating in this process should be open to and inclusive of all. An unidentified hazard is like unknowingly sitting on a ticking bomb waiting to explode.

B. Risk Assessment: Risk assessment is about quantifying the significances of each hazard. It is essential to determine if a possible impact of the hazard is acceptable or not, and to maximize effectiveness by focusing on the most important hazards first. Risk assessment is a well-defined process and is known to the intended readers. The outcome of the "Risk Assessment" step is a sorted list of hazards prioritized according to risk. Decisions and actions needed also follow the risk priority, and the risk of all hazards should be reduced to an acceptable level as defined by the organization through the implementation of "Risk Control".

C. Risk Control: The purpose of the risk control step is to reduce risk to acceptable levels. This is the most controversial step in practice as it involves analyses of the cost and benefits of various proposals to reduce the risk. The risk assessment method explained in the previous section should be used to measure the reduction in risk for each proposal, and make sure that the resulting risk would be acceptable after implementation. To come up with alternatives for risk controls, this cognitive model classifies all risk controls into five categories that are linked to the "source of danger", "Safety Target", and/or "Mechanism of Harm" explained in the "Hazard ID" block. The following is an illustrated example of how to control the risk of a fully defined hazard. Typically in a training session, the five types of risk controls are presented one at a time and are discussed concerning their effectiveness in reducing the probability and or severity of the hazard. Also, the discussion should include issues of implementation such as cost, time, and common practices.

The example is about controlling the hazard of "Dog biting child"(see Figure 2.1). It is a fully defined hazard according to the model, and the source of danger is the dog, the safety target is the child, and the mechanism of harm is biting. The example is abstract in form and it was chosen for its simplicity. For analyses, two questions are asked for each and all of the risk control types presented; "Does the control reduce the probability and/or the severity of the hazard?" and "What issues affect its implementation in practice?". The five types of risk control are:

- **Warning Signals and Signs:** Warnings are signals and or signs that serve to inform the "Safety Target" about the presence of the "Source of Danger" (see Figure 2.2)..
- **Administrative Controls:** Administrative controls are rules established by the administration to set standards for the behavior of the "Safety Targets" (see Figure 2.3).
- **Personal Protective Equipment (PPE):** PPEs are placed on the body (person) of the safety target, and it provides a protective barrier between the safety target and the source of danger (see Figure 2.4).
- **Engineering:** Engineering controls are protective barriers (guards) that are placed on the source of danger to prevent it from reaching the safety target (see Figure 2.5).
- **Elimination:** Elimination of the source of danger removes the hazard, but may create a new one if other sources of danger are introduced (see Figure 2.6).

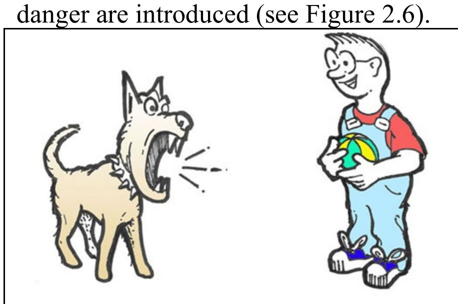

Figure 2.1: Example Hazard – Dog bite child.

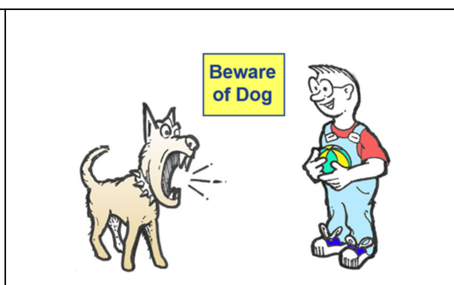

Figure 2.2: Risk Control – Warning Signals and Signs

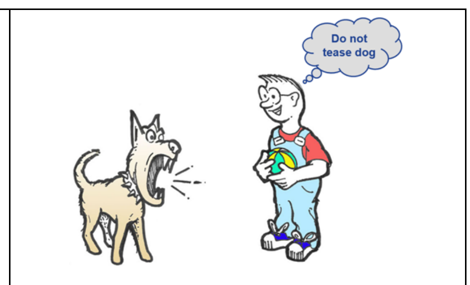

Figure 2.3: Risk Control – Administrative Controls

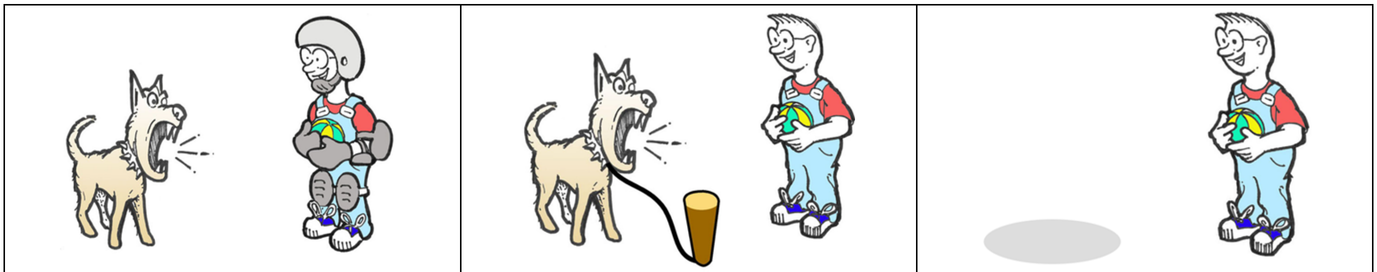

Figure 2.4: Risk Control – Personal Protective Equipment (PPE).

Figure 2.5: Risk Control – Engineering

Figure 2.6: Risk Control – Elimination

Figure 2. Five-Types of Risk Controls

Hierarchy of Control vs. Swiss Cheese Model: Both the hierarchy of controls and the Swiss cheese model indicates the types of controls used to make the risk of a hazard acceptable, i.e. safe. OSHA's hierarchy puts "Elimination" at the top as most effective control and puts PPE at the bottom as the least effective control (OSHA, 2002). The hierarchical order may poses a metaphorical fallacy of that the types of risk controls are in competition, resulting in discouragement of workers to use PPE. In contrast, the Swiss cheese model indicates that multiple types of risk controls work together to protect the safety target, and attention should be paid to all (see Figure 3). Also, OSHA's hierarchy of controls ignores "warning signals" although it is part of the framework for hazard communication. The Swiss cheese model is adopted for this SCM.

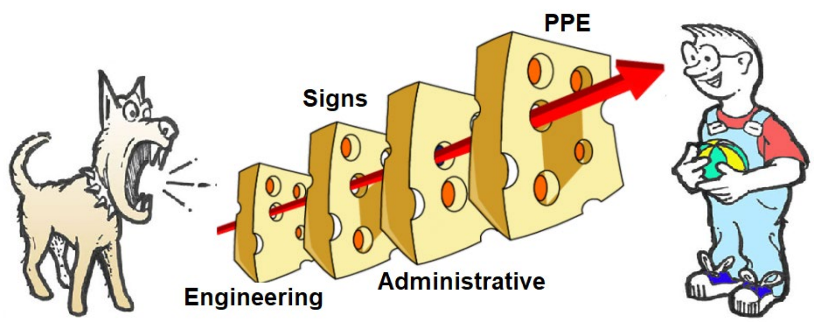

Figure 3. The Swiss Cheese Model of Risk Controls

2.3.2 Preparation

This section deals with what happens after the failure. The safety cognitive model divides preparations into three sections that help us focus on preventing serious injuries and having rational and proportional responses to failures and injuries. The sections are "Fail Safe", "Emergency Preparedness", and "Insurance".

A. **Fail Safe:** Fail-Safe implies that failure is inevitable but the injury should not be. Failing safe requires a clear definition of failure and an understanding of the mechanisms of harm. If failure can be detected early enough to intervene and stop the mechanism of harm, then injuries can be prevented. Having the "failing safe" concept part of the cognitive model is important, not only because it is the last resort to prevent injury, but also because it forces workers to anticipate failures which is essential for prevention too. Failing safe is not a new concept; examples include the Ground Fault Circuit Interrupters (GFCI), Sawstop©, and periodic health checkups in cases of chronic exposures.

B. **Emergency Preparedness:** Emergency preparedness is about having the resources and being able to properly respond to an injury or a significant loss.

C. **Insurance:** Insurance is about making sure that the business is sustainable even after suffering significant losses.

This completes the presentation of the safety cognitive model. It represents a complete guide for a comprehensive safety plan. As stated in the introduction this model shifts the focus from "unplanned accidents" to "planned safety".

3. Developmental Evaluations

Evaluations of the SCM during the developmental phases included "face value evaluations by experts", "comparative achievement tests", " surveys of learners' opinions", and limited assessments of safety performance of organizations. Although a conclusive result cannot be claimed from the aforementioned developmental research, it can be said that the use of a cognitive model made safety training easier for both the trainees and the trainer. Trainees preferred using a model; it helped them achieve more, understand deeper, and positively adjust their attitudes and behaviors. Also there was agreement by safety experts that a unified cognitive model has the potential to improve communications within organizations and between organizations, especially with regularity departments. The proposed model is quite complete, however, research is needed to evaluate it more rigorously and further improve it.

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