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A Cognitive Model for Teaching and Training in Occupational Safety and Health

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Abstract: This paper is about improving Instructional Design (ID) for safety education through the use of a simple and comprehensive Safety Cognitive Model (SCM). Well-structured cognitive models make both teaching and learning easy, produce deeper understanding, and are more appealing to learners. The proposed SCM contains no new safety knowledge, but rather organizes and presents information in a novel manner. This paper consists of a discussion of essential background on learning and the importance of having a comprehensive and unified cognitive model for safety, a "pictorial essay" encompassing ten original illustrations that constitute the proposed safety cognitive model, and the final part includes experts' evaluation of the model as it is presented in this paper. Twenty-three safety professionals were asked to review the SCM; they were requested to fill in a survey and provide any additional comments or personal thoughts. Results indicated that the model was not entirely novel, but it rather organized all the basic safety principles in an integrated, holistic, and simple model. Recommendations are made for independent evaluations of the model for further improvements. This paper is written for experienced safety professionals, as it assumes knowledge of safety basics.

Keywords: Safety Training, Safety Cognitive Model, Training Efficiency, Evaluation of Training.

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1. Introduction

Systematic reviews of the literature concluded that there is sufficient evidence to support that safety training indeed increases workers' knowledge, helps alter unsafe behavior, and reduces injury rate (Fischer, 2015; Johnson et al., 1987; Kontogiannis et al., 2017; Bayram, 2022; Cowan, 2014; Tracy et al., 2006). Though evidence exists for the effectiveness of safety training, efficient ways to train workers remain debatable.

Several aspects of occupational safety and health training make learning more difficult for students and workers alike. Indeed, the extent of teaching material is massive and not well-organized for easy learning. For example, the safety requirement for the general industry in the USA comes in 700+ pages. Most times, after completing a training session, workers find themselves with lists of dos and don'ts that are very long and beyond the capacity of an average human to fully memorize or retain. Other aspects include inconsistencies in definitions of safety-related terms in literature. For instance, the definition of "accident" has been the topic of multiple publications, and the adopted definitions in different fields are still lacking in clarity and comprehensiveness. Furthermore, the field of occupational safety and health is also relatively new and evolving. Safety management approaches have changed since the OSHA Act in 1970 (Taylor et al., 2007; Fischer, 2015; Johnson et al., 1987; Kontogiannis et al., 2017; Zanko et al., 2012). Few safety management standards have been issued and only some are widely accepted in the industry. However, the basics of what safety is and how it can be achieved remains elusive for the average worker/person.

The path from information that appears scattered in documents, to creating a holistic understanding in the learner's brain passes through a memory bottleneck. Understanding a human's cognitive abilities is crucial to successful safety Instructional-Design (ID) (Bonilla-Escobar et al., 2014; Fu et al., 2019). 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 learning. It is fundamental to design instructional materials that suit the memory capabilities of learners (Fu et al., 2020; Tracy et al., 2006; Zanko et al., 2012; Grant et al., 2018; Ge et al., 2022).

This research aims to improve the efficiency of safety training by analyzing training from both learning and an ID point of view. Indeed, it focuses on cognition of basic concepts of safety, what it is, and how it can be achieved. It proposes a simple and comprehensive Safety Cognitive Model (SCM) that has the potential to make learning safety easy for college students, workers, and maybe school youths. The process for developing the SCM was iterative, for the model kept evolving over many years, based on expert assessment, as well as learners' performance and preferences.

The intended readers are inclusive of experienced safety professionals from all fields, especially those with training/teaching duties. Specific details from cognitive engineering are presented. However, explanations of safety-related information and concepts are minimal.

1.1. Learning

When people learn something new, a cognitive model is created in their brains. Cognitive models are usually images that appear in the brain in response to stimuli. For example, when one hears the word "apple", then an image of an apple appears in the brain and that fairly explains what is understood by the word "apple". Similarly, a made-up word such as "Fonkaluse" will trigger no imagery in the brain because it is not understood. A universal or common cognitive model makes communications better and facilitates cooperation. Think about how much harder it would be to verbally explain what an "apple" is to someone who does not know what "apple" is. "A picture is worth a thousand words" is an adage popular in many cultures and in multiple languages around the world. It means that complex multiple ideas can be conveyed by a single still image more effectively than a mere verbal description. Therefore, thousands of words are enclosed in a picture to make safety easy to understand.

Models, by definition, are simpler and smaller than what they represent, and their function is to create comprehension or understanding of reality. For example, an architectural model would be placed on a relatively small table inside the same building it represents. It is much smaller than the real building, but it helps visitors easily understand the layout of the space around them. How well models function depends on the complexity and level of detail presented in the model. Too many or too few details are counterproductive.

Cognitive models represent the knowledge learned, and that shapes attitudes and behavior (Fu et al., 2019). Literature is filled with cognitive models for safety-related concepts, such as the Swiss cheese model, the reversed safety pyramid, the safety pyramid, and many others. Also, many versions of these models exist, which may be confusing. Currently, cognitive safety models are inadequate, and there is not one cognitive model that is inclusive of all aspects of safety.

1.2. Human Capacity

Long-term memory is the permanent storage of information in the brain, it has a very large capacity, and many researchers hypothesized that humans -on average- use less than 20% of it. Long-term memory is filled with all sorts of life experiences across all ages. However, only limited information can be recalled at a time. Working memory is the cognitive process responsible for recalling information stored in long-term memory. Working memory is also crucial for learning and refers to the ability to hold and manipulate information mentally over short periods. Many metaphors have been used to explain memory types and their interrelationships. For example, The Globe can be explored through the Google Earth app on a cell phone. The world represents the long-term memory, and what can be seen on the screen represents the working memory. You can only see a screen full at a time, and each zooming level will present a different layer of meaningful information. Working memory is limited both in capacity and duration. The average adult cannot hold more than seven bits of information at a time in their working memory. Almost all humans will find it easy to memorize three things at the same time, but most of us will find it difficult to memorize ten things. The difference between easy and difficult is in the capacity limitations of the working memory. The higher the demand for memorizing or recalling things, the more difficult the task is and the higher the chance for errors (Bonilla-Escobar, 2014; Fu et al, 2019). Hence, organizing new 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" (Bayram, 2022; Fu et al., 2019). Chunking is grouping multiple things into one as per a unified category. For example, the division of a lifetime into years, months, weeks, days, and hours is a good example of chunking. Time chunks make it much easier for communication. Reducing the demand on the working memory by chunking, make it possible to handle more information, and therefore increase learnability. Chunking multiple things together is tricky and requires a deep understanding of the whole system. Chunks and their interrelations make the cognitive model; therefore, it is up to experienced safety professionals to construct a cognitive model that will make learning safety easy.

1.3. Metaphorical Fallacy

Models, metaphors, and analogies are all that we have to explain abstract concepts such as "Safety". An integrated, simplified, and comprehensive cognitive model for safety has the potential to make learning safety easy, thus reducing injuries and suffering in the long term. However, the use of a non-optimum cognitive model may lead to non-optimum understanding and unsafe behavior. "Metaphorical Fallacy" is the mistaken belief that one metaphor provides an adequate cognitive frame for a given abstract concept. Learners may take a cognitive model beyond its intended limitations, and extrapolate unintended meanings (Gao et al., 2019; Gobet et al., 2001; Cowan, 2014). Adopting a cognitive model for safety should be carefully done to ensure effective understanding and proper behavior.

Having a common cognitive model for safety means that workers, management, and safety professionals all share the same safety language, beliefs, and values, which in turn will increase cooperation between them all and lead to safer workplaces. In addition to that, a universal "simplified" safety cognitive model may reduce the cost of training, the burden of learning, and help in effectively delivering safety education for school students.

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 and is assumed to be known to safety professionals; however, the uniqueness of the SCM is in the way the information is organized to facilitate learning. The SCM is comprehensive of basic concepts essential for effective safety learning and practices. It is also simple as it presents 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 consistent with risk management principles (Angelopoulou et al., 2021; Waehrer et al., 2009; Hamington, 2009; Amundrud et al., 2017**)** and applies to occupational safety and health as well as other fields, including environmental protection.

2. Method

This section consists of the SCM description, and the research methodology used to gain experts' evaluation.

2.1. The Proposed Safety Cognitive Model

The SCM is a three-level tree plot, as shown in Fig. 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 then 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.

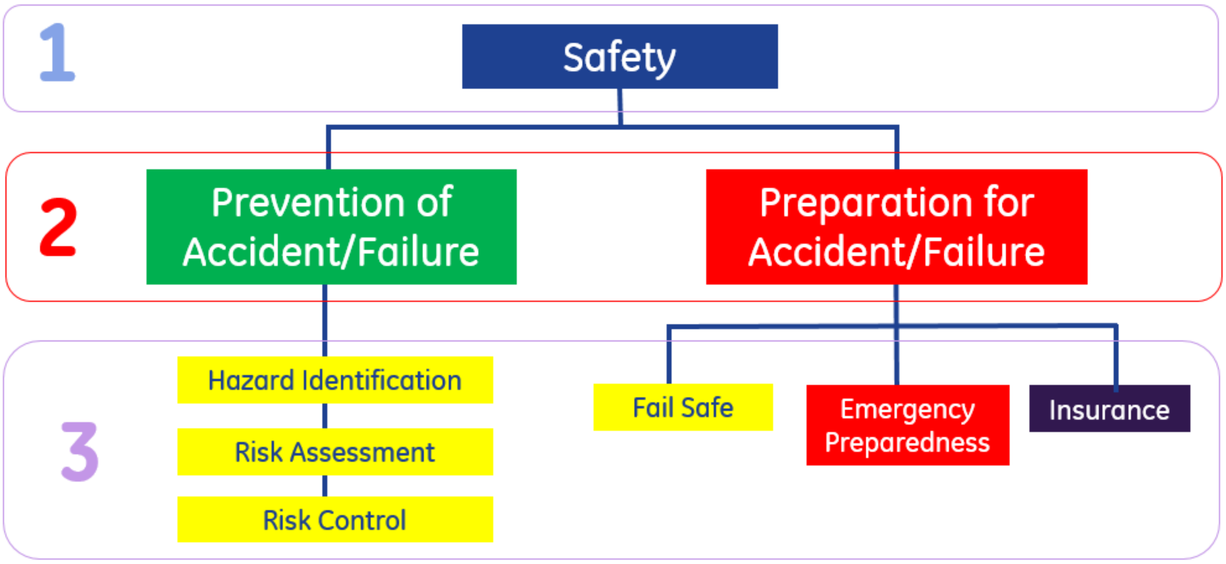

Fig. 1. Safety cognitive model

2.1.1. SCM - Level One

The "Safety" block is at the top of the model, and it represents safety that is achieved through all the branches below. In other words, to achieve safety, all six blocks at the third level of the model should be addressed or executed. Although the third level contains details of what needs to be done, starting at the top level is very important to establish a clear "Safety" concept. Therefore, defining what safety is and when people feel safe is crucial and is recommended through open discussion in training sessions. It is almost certain that the discussion will necessitate arriving at the definition of an accident, as most would define safety as having no accidents.

In the pursuit of a definition of accidents, it is important to explain the following:

- "Accident" comes from accidental, i.e., unintentional or unplanned; however, these explanatory expressions may have a regressive effect. One major common belief associated with accidents being unplanned is that some will 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 both individuals and organizations have the power and the choice to be "Safe." "Unwanted" may be a better word 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 also be collectively described as "failures." This is linked to the afore-mentioned point that "safety is planned" and thus, accidents are associated with some type of failure.
- The distinction between "injury" and "failure" in the definition of an accident is an important concept for workers. For instance, in "zero accident" programs, workers may feel overwhelmed and disappointed when an accident happens. In contrast, the idea of distinguishing injury from failure motivates workers to think about stopping injuries by anticipating failures. In addition to that, this distinction between "cause and effect" helps in establishing the idea that "absolute safety" does not exist. Failures are inevitable as "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 (Fischer, 2015; Dowding, 1995; Waehrer et al., 2009; Hamington, 2009; Lyu et al., 2022).

The proposed safety model is based on the following definitions:

- Safety is achieved when the probability of bad things happening is acceptable.
- Accident is an unwanted significant harm or loss caused by human error, equipment malfunction, material, as well as 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".

One of the goals of redefining "accident" is a simplification; therefore, no distinction is made between chronic and acute events. The new model provides a simple framework to understand and manage safety regardless of the type of exposure. This does not cancel the actual differences between acute and chronic but rather provides an abstract model that applies to both, therefore making "safety" cognitively easy.

2.1.2. SCM - Level Two

Level two in the cognitive model states the "strategies" for achieving safety. Based on the concept of "Absolute safety does not exist" that was established in level one of the SCM, the strategies for achieving safety must include both prevention of accidents through the prevention of failures and preparing for when accidents and failures happen or occur. Of course, an ounce of prevention is worth tons of preparation, and working toward both simultaneously might seem contradictory, but it is fundamental to achieving safety. In the prevention side the aim is to prevent injuries by preventing failure. So, an explicit label for this block would be "prevention of failure." The Preparations side includes preparing for both failures and injuries. The distinction between failure and injury is important as it allows for the prevention of injury even after the failure has occurred. Furthermore, preparations for dealing with failure are different from those needed to deal with injuries.

2.1.3. SCM - 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 "whats" and "whys" of what workers do for safety at the operational level. There are three blocks for each of the "Prevention" and "Preparation" blocks.

2.1.3.1. Three sequential steps for prevention

2.1.3.1.1. Hazard ID

Anticipation of failure is crucial to achieving safety. In other words, one cannot protect him or herself from what one 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 be delayed until the safety model is explained. At this time, 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 as follows:

- 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 humans. The target information may include all of those listed in the organizational chart: workers and management, customers, suppliers, and/or visitors and neighbors. For example, the target could be "the driver" of a vehicle that is being designed or "all people in a room" where a harmful chemical is present in the air.
- The Source of Danger is the second piece of information that is needed to fully define a hazard. It is about what could harm the safety target. It is important to link the source of danger to locations, equipment, and or activities. In our previously mentioned examples, the sources of danger could be "vehicle crash" or "chemical present in a room". Furthermore, the sources of danger may be classified as chemical, mechanical, electrical, and so on. Classification of sources of danger would facilitate the implementation of safety training programs. For example, one can identify potential attendees for an electrical safety training session by searching the database of the hazards for "safety targets" with exposure to "electrical" sources of danger.
- The third essential piece of information needed to fully define a hazard is the "Mechanism of Harm." It 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". It is also important to identify sequential steps that lead to the occurrence of harm, as it could help in identifying specific actions that can be taken after 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 from the impact of each hazard on the organization. The focus should be on identifying all hazards and fully defining each one. Participation in this process should be open to and inclusive. An unidentified hazard is similar to unknowingly sitting on a ticking bomb waiting to explode.

2.1.3.1.2. Risk assessment

If hazard identification is about finding potential problems, then risk assessment is about quantifying these problems. Quantifying safety problems is essential for proper management. On one hand, one wants to determine if a problem is acceptable or not, and on the other hand, one wants to maximize effectiveness by focusing on the most important problems first. As defined earlier in Level One, safety is when the probability of bad things happening is acceptable; therefore, it is essential to quantify both the probability and severity of a hazard. Multiplying probability with severity produces a combined quantity called “Risk.” A high number of risks could come from a high probability to occur, and or high severity. Of course, low risk means that the probability and severity are low, and therefore, the hazard is safe. It is important to have a systematic method of evaluation to ensure objectivity and avoid bias. The risk assessment process should involve trained representatives from management and workers, as well as the usage of specific scales. The process is not an exact science, but its objectivity in assessment is suitable for safety management. The main purpose of risk assessment is to determine what action/s needs to be done. For example, hazards having less than the acceptable risk levels need no action whatsoever, so there should be a limit on high risk beyond which activities should immediately be suspended. Between the high and low limits of risk, work activities may continue, but with added means and precautions to reduce risk in the short and/or long terms. Therefore, the risk assessment process should help management make these decisions.

To manage occupational safety and health, subjective scales for probability and severity have been widely used and accepted. Also, assembling and training the proper risk assessment team will eventually lead to unbiased assessments that both management and workers can agree on. A typical risk code matrix is shown in Fig. 2. The columns represent five levels of severity, and the rows represent five levels of probability. The numbers within each cell of the matrix are the risk, and the color of the cell indicates the needed action/s management should pursue. Green indicates low risk where nothing is needed, red indicates high risk and management should immediately cease activities, and yellow indicates that actions should be implemented for short and/or long terms.

RISK MATRIX

PROBABILITY →					
Very Likely - 5	5	10	15	20	25
Likely - 4	4	8	12	16	20
Possible - 3	3	6	9	12	15
Unlikely - 2	2	4	6	8	10
Very Unlikely - 1	1	2	3	4	5
	1	*2*	*3*	*4*	*5*
	Negligible	*Slight*	*Moderate*	*High*	*Very High*
	SEVERITY →				

Risk	Risk Level	Action
1 to 6	Low Risk	Risk is acceptable; monitor and review performance periodically.
8 to 12	Medium Risk	Task should only be undertaken with appropriate management authorization after consulting with safety specialists. Long-term goals should target task for redefining.
15 to 25	High Risk	Stop task, redefine and control risk to acceptable levels.

Fig. 2. Typical risk code matrix

Having an equal representation of workers and management on the risk assessment team is key for successful evaluations. Management tends to underestimate risk, but workers are on the contrary, so together they will arrive at accurate and acceptable assessments. All members of the assessment team don’t need to converge on the same number for risk. However, if a large variation appears between the assessors, a re-vote may be necessary after allowing for a brief discussion. If the larger variation is still present in the second vote, it is best to take the average of all numbers and move on to the next assessment. The assessment method should be clear, and pre-established rules should be followed to avoid conflicts or unnecessary delays.

The outcome of the “Risk Assessment” step is a sorted list of hazards prioritized according to risk levels. Decisions and actions needed should follow the risk priority defined in the risk code matrix. The acceptable risk may vary for many reasons, including culture, activity, and importance of target. The risk of all hazards should be reduced to an acceptable level, as defined by the organization, through the implementation of “Risk Control.”

2.1.3.1.3. 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 reduction in risk of each proposal and make sure that the resulting risk is acceptable before 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 discussed according to their effectiveness in reducing the probability and or severity of the hazard. Also, discussion should include other issues of implementation such as cost, time, and common practices.

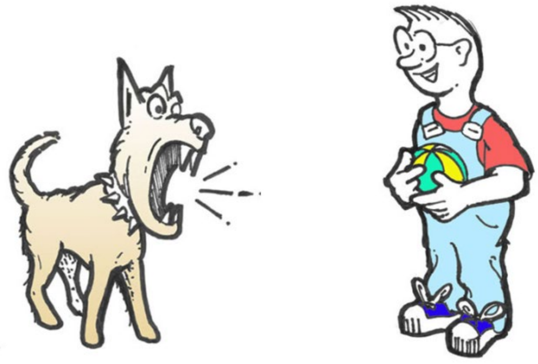

Fig. 3. Example hazard – dog biting child.

The example is about controlling the hazard of "dog biting child." 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. An explanation of the situation may be presented as the child is playing with a ball in an open area without fences, and the neighbor's dog is not friendly (Fig (3)). The five risk controls are presented below in ascending order, starting with the least effective and ending with the most effective control method. 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?".

I. Warning Signals and Signs

Fig. 4. Risk control – 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". It could be text, pictographs, sounds, lights, and or anything that the "Safety Target" can sense and interpret. Their effect on severity is almost none; for instance, the severity of the dog's bite would not change with the presence of a warning sign. Warnings mainly reduce risk by reducing the probability, however, the reduction is small and it depends on the ability of the safety target to sense and interpret it. Therefore, text warnings should be presented in the workers' language, and pictographs should be accompanied by training on their meanings.

Warnings usually are not expensive to implement, however, they should be inspected and maintained periodically. Self-explanatory signs and signals are recommended, but also safety training should include explanations of signs used both locally and internationally such as ISO's and NFPA's standard signs.

Warning signals and signs should stand out and be kept clean at all times. Continued effort is needed to maintain an effective presence of signs and signals as people tend to get used to them and then ignore them.

Warnings may be required to satisfy legal issues concerning the workers' right to know.

II. Administrative Controls

Administrative controls are rules established by the administration to set standards for the behavior of the "Safety Targets" and others around them. In our dog-biting-child example, administrative controls are instructions given to the child to stay away from the dog, not to throw the ball in the direction of the dog, and so on. Again, this type provides no barrier between the dog's teeth and the body of the child. Therefore, the effect of reducing the severity is minimal. It can be argued that training the child to avoid bites to the face and neck would reduce the overall severity, but on this side of the safety model, we are concerned about preventing failures as means to prevent injuries. Such instructions may reduce the overall severity and will be included in the discussion of the "Fail Safe" block of the model as it comes into play after the failure which in our case is "dog attack child". Administrative controls reduce risks by mainly reducing the probability of failure. It is implied that achieving safety in this case is a function of how well humans behave properly. However and because to err is human, implementing administrative controls is associated with residual risks.

Fig. 5. Risk control – administrative controls

In practice, implementing administrative controls may be costly and lengthy, because of the expenses and time associated with training employees. In some cases, retraining or refresher training may be required to maintain the effectiveness of control. Also, to avoid complacency, there should be ways to deal with inappropriate behavior, such as having disciplinary procedures.

Administrative controls are by definition counting on the safety target to follow instructions, and it also includes any situation where humans other than the safety target are supposed to follow instructions, such as the lifeguard in a swimming pool.

III. Personal Protective Equipment (PPE)

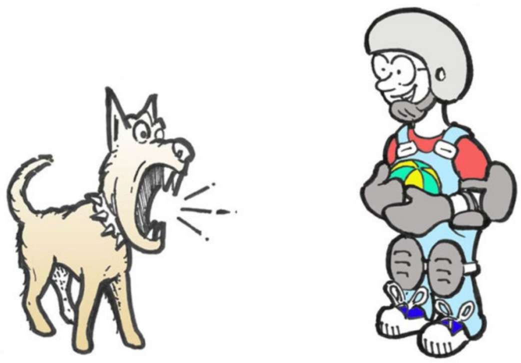

Fig. 6. Risk control – Personal Protective Equipment (PPE).

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. It includes all garments we wear for safety, and it prevents the source of danger from reaching the vulnerable parts of the safety target. Unlike warning signals and administrative controls, PPEs provide a physical barrier and may reduce the probability and or the severity of a hazard. However, its effectiveness is limited by how it's used. The following issues are known to hinder the effective use of PPEs:

- The reluctance of workers to use PPEs if uncomfortable, interfere with their job, and or believe that it is unnecessary or ineffective.
- Cost
- Administration of PPEs may be cumbersome and expensive and requires procedures:
  - Proper selection of PPEs
  - Workers' training on proper use and maintenance of PPEs
  - Securing workers' buy-in through leadership and choices of PPEs
  - Enforcement and disciplinary procedures

In their recommended practices, OSHA puts the use of PPEs at the bottom of their hierarchy of risk controls (OSHA, 2023). Although OSHA similarly explains the shortcomings of PPEs, as mentioned above, workers may be discouraged from using their PPE because of the perceived "least effective" rating (Hamington, 2009). Ample evidence exist that PPE works, and workers should be encouraged to use it as required by their work.

IV. Engineering

Fig. 7. Risk control – engineering

Engineering controls are protective barriers (guards) that are placed on the source of danger to prevent it from reaching the safety target. It is very effective and it can reduce both the probability and severity of a hazard. In the dog-biting-child example, having the dog chained creates two zones: the small circle that the dog can reach, and the remaining area, including where the child is playing. Within the small circle, the probability that the dog will attack is as high as the severity, and in the remaining area, the probability is equal to the probability that the dog chain breaks. By keeping the source of danger confined to an area where the safety target should not enter, the risk is kept low, and safety is achieved.

Engineering controls may require a high level of skills in design, and lengthy prototyping and implementing procedures. Additionally, associated costs tend to be high. In creating a special area for the source of danger to exist, procedures for entering this area should be implemented.

V. Elimination

Fig. 8. Risk control – elimination

Elimination of the source of danger removes the hazard; therefore, it is the most effective risk control. Eliminating the dog in our example reduces the risk of the child being bitten by the dog down to zero unless the neighbor insists on having a pet. The neighbor may replace the dog with a friendly cat or with a more aggressive dog or animal, and then a new hazard is introduced and must be assessed and controlled separately. Eliminating the source of danger or substituting the source of danger with a much less harmful replacement are two sides of the same coin and are considered the most effective way to control risk. Worth mentioning is that OSHA's hierarchy of control has separate categories, one for elimination and another for substitution (Hamington, 2009, OSHA, 2023). In this cognitive model, substitution is elimination but with the introduction of a new hazard that must be included in the list, evaluated, and controlled.

Applicable Solutions and Implementations Preference: As can be seen from the forward presentation of the types of risk controls, it is easy and systematic to come up with solutions to reduce risk once the hazard is fully defined. Simply answering the following questions will create a focus on solutions and alternatives that might reduce risks to acceptable levels:

- Can the source of danger be eliminated or replaced with a safer substitute?
- Can the source of danger be confined to an area where the safety target may not enter through the use of physical barriers, guards, or other engineering means?
- What PPEs are appropriate?
- How the "safety target" should behave to stay safe?
- What warning signals should be used to inform the "safety target" about the proximity of the "source of danger"?

The order of the previous questions should also guide the selection of risk controls with number one as the most preferred. In practice, controlling the risk of a hazard is usually done through the use of multiple risk controls. Enough controls should be used to bring the risk down to an acceptable level and must be verified through the risk assessment procedure before implementation. In the "dog biting child" example, a combination of chaining or fencing the dog, having a warning sign, and training the child not to enter the area may bring the risk to an acceptable level in most cases.

Hierarchy of Control vs. Swiss Cheese Model: Both the hierarchy of controls and the Swiss cheese model indicate the types of controls used to make the risk of a hazard acceptable, i.e., safe. The hierarchy of risk control is usually presented as a reversed triangle or pyramid with the base on top and pointing downward. OSHA's reverse pyramid has "Elimination" at the base as the top effective control and PPE at the bottom as the least effective control. This comparison may result in distorted cognition that the controls are in competition, resulting in discouragement of workers to use PPE. The Swiss cheese model is used to explain the occurrence of system failures, such as accidents. According to this metaphor, a source of danger is prevented from causing human losses by a series of barriers. Each barrier has unintended weaknesses or holes – hence the similarity with Swiss cheese. These weaknesses are not constant – i.e., the holes open and close. When by chance all holes are aligned, the source of danger reaches the safety target and causes harm (Fig. 10). 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. It shows that engineering controls and warning signs are positioned close to the source of danger, and PPE and administrative controls are close to the safety target. For this safety cognitive model, the Swiss cheese model is adopted, and the idea of preference in the implementations of control types is addressed in the questions listed above.

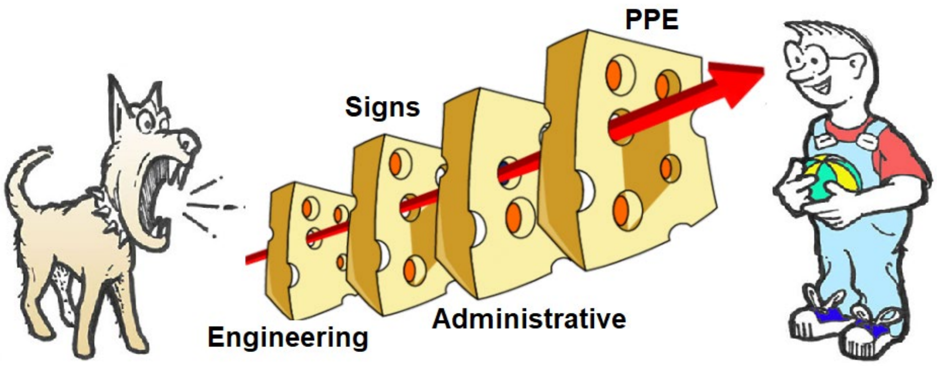

Fig. 9. The Swiss cheese model of risk controls.

2.3.2. Three Parallel items for "Preparation"

As stated, the safety cognitive model has two sides; the one on the left is explained in section 3.1 and deals with preventing failures as means to prevent injuries, and this section which deals with failures, injuries, and losses. It is conventional wisdom to focus on prevention rather than cure. However, no safety plan is complete without addressing preparations for failures and or injuries. All of discussed in this section is about what happens after failure. The definition of failure is different from the hazard. While the example hazard introduced in the previous section was identified as "dog biting child," the failure is "dog attacks child". Not every attack will result in a bite, and not every bite will produce severe injury. Therefore, 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".

2.2.3.2.1. 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. For example in a car crash, the failure may be defined as "unrestrained movement of the human body that results in striking it against hard objects". Both the airbag and the seatbelt demonstrate the two phases of failing safe. First sensing the failure; seatbelts are designed to restrain if pulled fast, and airbags have electronic deceleration sensors that will trigger explosives to inflate a bag in case of sudden deceleration that is typical of a harmful crash. Secondly, interrupting the mechanism of harm; the seatbelt will restrain the human body from moving forward, and the airbag introduces a somewhat soft pillow-like object between the human body and the steering wheel or dashboard.

Another example from construction work is the use of a safety net. If a worker falls from a height, a safety net will catch him or her before hitting the ground resulting in a safe failure. The difference in this example is that there is no sensing of failure and the net is deployed at all times.

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 are essential for preventing failure as well as for failing safe.

Failing safe is not a new concept, and many products have been designed based on it. To mention a few, Ground Fault Circuit Interrupters (GFCI) prevent electrocution even after coming in contact with a bare electrical conductor, and Sawstop© prevents cuts and amputations even after coming in contact with a high-speed rotating saw blade. Chronic exposures, such as occupational diseases and failing safe require periodic health checkups and tests. The implied goal here is that if caught early diseases might be reversible or at least easily controllable without affecting workers' lifestyles.

Failing safe comes in a format similar to the types of risk control. Typically, it is "Engineering" as in the GFCI case, "Administrative" as in the periodical health checkups, and PPEs as in the auto seatbelts. In some cases, confusion might rise as to whether a PPE is a risk control or a failsafe device. The short answer is if it comes into play after the failure happens, then it is a failsafe device by definition. Furthermore, it is important to realize that the goals of the safety cognitive model include simplifying knowledge and empowering workers to achieve safety. However, it is important to ground the discussion by explaining that the cognitive model is designed to help workers be comprehensive in their approach to safety. Workers are recommended to question their definition of the failure of each hazard and revise it if necessary. Typically, this discussion appears at an advanced stage in the training; after completing the prevention side of the model, which is the most important, and during the first stage after realizing that failure has happened but still wanting to prevent injury. Such discussion indicates deeper levels of understanding and a sign that the training is effective.

2.2.3.2.2. Emergency Preparedness

Emergency preparedness is about dealing with injuries. Having the plans and resources to provide immediate medical care, transportation of the injured, communicating with internal and external customers … etc. While some of the hazards are universally common such as fire and personal injuries, preparedness should be linked to specific hazards identified at the workplace.

In general, emergency preparedness is strongly regulated to protect workers' rights for treatment and compensation. Usually, in case of an emergency, the responsibility of each worker is defined; ranging from evacuation, sheltering in place, to having specific responsibilities. Those with duties to rescue, provide first aid, or have any specific functional or operational responsibilities are trained and their skills to do so are formally verified. The purpose of this article is to introduce the safety cognitive model, and therefore the discussion of emergency preparedness is limited to highlighting where emergency preparedness fits in the model.

2.2.3.2.3. Insurance

This is the third and last part of the "Preparation" side of the model. The first part was about preventing injuries by failing safe, and the second part was about being prepared to respond to injuries or significant losses to lessen the impact on business. Having insurance is about making sure that the business is sustainable even after suffering significant losses.

Insurance may be compulsory such as "workers' compensation", or voluntary such as "fire insurance". For both types, the amount a business pays for insurance is proportionate to the risks of the hazards at the workplace. Typically there are no specific roles for individual workers, but they need to comply with safety rules required by the insurance.

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". The six blocks on the third level of the safety cognitive model represent major sections in any safety plan. It can be stipulated that a complete safety plan should answer the following six questions:

1. What could go wrong? (Hazard ID)
2. How big is the problem? (Risk Assessment)
3. What can be done to prevent failures from happening? (Risk Control)
4. Is it possible to stop failures from becoming injuries? (Fail Safe)
5. What resources should be prepared to respond properly to an emergency? (Emergency Preparedness)
6. Can I afford not to have insurance? (Insurance)

It can be seen from the model that answering questions 2 through 5 requires that question 1 be answered first. Therefore, hazard identification is key for safety planning. All hazards should be identified and fully defined. An unidentified hazard represents an assumed risk of an unknown quantity that might be too high. Hazards at any workplace can be identified systematically, by accumulating a list of all hazards. Processes for identifying all hazards may be grouped into three categories as shown in Fig (10); Predetermined, Job Safety Plan, and Ongoing.

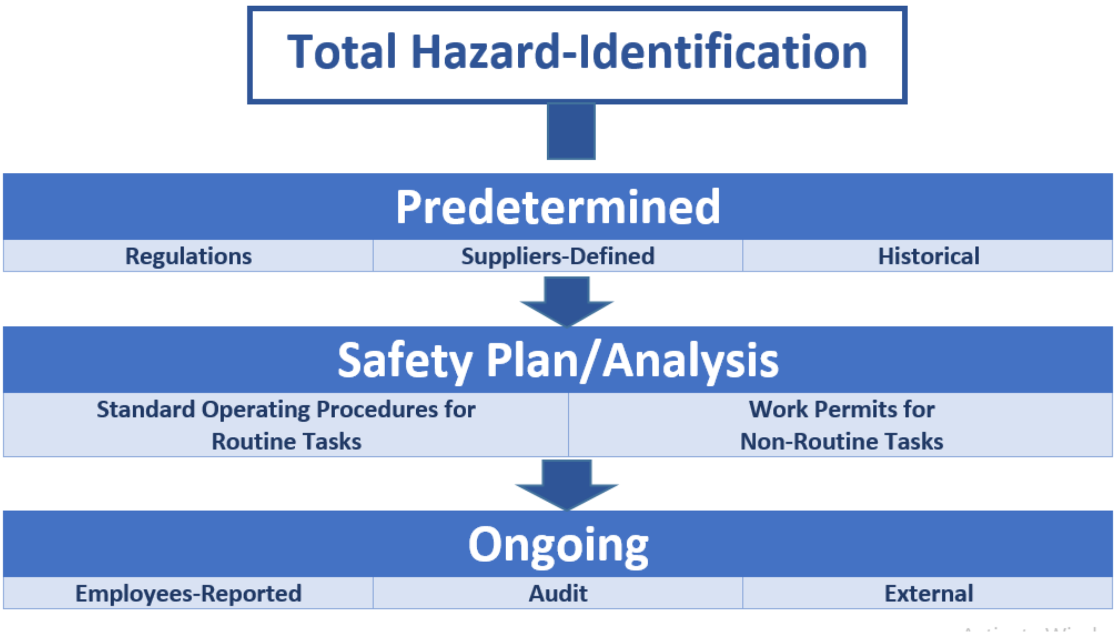

Fig. 10. Total hazard identification

Predetermined hazards are hazards that have been identified before even the business idea started. It includes hazards associated with equipment and material used at work; such are listed in Safety Data Sheets (SDS), operation manuals, and other documents provided by the suppliers. Similarly, safety regulations are also predetermined and represent hazards that must be controlled in ways that are acceptable to the government. In addition to that, "Historical Hazards" may be identified through documented or non-documented historical events at the workplace. Each accident, incident, and first aid case that happened in the past identifies a hazard and fully defines it.

The second category of hazards is those discovered through the analysis of tasks and the creation of a safety plan for each. This is the same as carrying out Job Safety Analyses (JSA); starting with the predetermined hazards for a job or task, workers break down tasks into steps and identify hazards and figure out the best way to control their risk. It is simply the process of planning for safe work. It involves answering the aforementioned six questions of a safety plan. The outcome of JSA is a safety plan that may vary in detail according to the complexity of the task. For routine tasks, the outcome represents a Standard Operation Procedure (SOP), and for non-routine tasks, it represents a "work permit" that describes the safe way the task must be done.

The third category "Ongoing" includes hazards that may appear as the job unfolds. It could be any nonconformity to the safety plan discovered or noticed during audits or inspections. It could also be something different or new to the established safety plan that workers experienced as a "near miss" or something they observed. Ongoing hazards reported by front-liners are crucial to staying ahead in preventing injuries. For workers to overcome the discrepancy between prediction and occurrence, their normal perception of probability should be altered (Illeris, 2018; Gallistel et al, 2014). Two safety-related examples can help modify workers' understanding of probability and encourage them to report incidents. The first example is about the chances of a car crash if a driver does not stop at a road intersection. The second example is about if a brick falls from a scaffold, then what are the chances that it will hit someone? Both examples can be used to differentiate between accidents and incidents in outcomes and frequency. Workers must be convinced that reporting an incident will make their job safer.

The ongoing identification of hazards at any workplace should also include ways to enable personnel to follow external safety developments in their fields, such as subscriptions to trade journals and memberships in professional associations. These will help in the identification of hazards that are associated with accidents, events, or new developments at other similar workplaces.

4. Method

The SCM in its current form was evaluated by safety experts twenty-three safety experts with minimum of 5-year experience in the field participated in this study, and they constituted 43% response rate. All received a document describing the safety cognitive model, were asked to share their thoughts and comments in an unstructured way, and to answer a 5-question survey (see Table 1).

5. Results and Discussion

In general, there was an agreement among consulted safety experts that the model is novel as it simply organized important safety-related information. The achievement testing for students was based on the overall grades in the "occupational safety and health" class over the many years the model was in development. The average grade and the percentage of students achieving B grades or better were contrasted. The base data were for three semesters that were taught in a conventional way and constituted the reference level for comparison. A similar test was developed and used to test the learning achievements of workers. Certainly, the variability in conditions was high, but results seemed to indicate that the time spent explaining the model at the beginning of the semester or the training session helped students and workers achieve higher grades. Additionally, the amount of information presented and discussed per semester or training session increased significantly. In comparison to the conventional ways, it was much easier and required less time to present safety topics such as "fire safety" after having completed the safety cognitive model.

Learners' evaluation was also helpful for the development of the CSM. In many cases, learners had previous training on the same topics or very similar ones and provided insight into the strengths and weaknesses of the cognitive model. The general sentiments were mainly positive, however, 3-5% of the trainees in the USA indicated that the model confused them and it would have been better if the training focused on OSHA regulations. The majority of the feedback was extremely positive, especially from those receiving their first formal safety training.

Evaluations of organizations' safety performance were limited and produced mixed results. Mainly, they were unchanged, but in a few cases they were slightly improved. These types of research require long time commitment from organizations which in practice is hardly achieved.

The results of the most recent evaluation by experts are shown in Table (1). In summary, responses indicated that the model is novel, integrated and comprehensive, clear, and would enhance workers' understanding and shorten training time. Although the experts were largely consistent, the biggest disagreement was about the question of novelty; two disagreed and another two were neutral. Those participants thought that the model was not entirely novel, but it organized all the basic safety principles in an integrated and simple way. Overall, their comments were consistent with their responses to the survey, and additionally raised the concern of lengthy adaptation process for those who are already trained on safety.

Table 1: Experts' responses to survey-questions

	Question	*Response		
		Avg.	Min.	Max.
1	The safety cognitive model is novel	3.95	2	5
2	The safety cognitive model is comprehensive of basic concepts	4.86	4	5
3	The safety cognitive model is simple and clear	4.71	3	5
4	The safety cognitive model would enhance workers' safety understanding	4.71	3	5
5	The safety cognitive model would decrease the overall safety training time	4.43	3	5

*Values based on 5-point agreement scale; 1: Strongly disagree, 2: Disagree, 3: Neutral, 4: Agree, 5: Strongly agree.

6. Conclusion

The results of the developmental evaluations collectively indicate that teaching safety using the proposed integrated cognitive model is superior to conventional alternatives that use fragmented models. It can be said that the use of 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. It was also indicated 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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