Pak. j. life soc. Sci. (2024), 22(2): 7820-7831 E-ISSN: 2221-7630;P-ISSN: 1727-4915

Pakistan Journal of Life and Social Sciences

www.pjlss.edu.pk

https://doi.org/10.57239/PJLSS-2024-22.2.00589

RESEARCH ARTICLE

The Role of Epistemology in Engineering-Based Occupational Health and Safety Management Systems

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ARTICLE INFO

Received: Aug 12, 2024

Accepted: Oct 4, 2024

Keywords

Epistemology

Occupational Health and Safety

Deming Cycle

Popper's Falsificationism

Risk Management

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ABSTRACT

This article explores the role of epistemology in the development and application of Occupational Health and Safety (OHS) Management Systems within engineering. By employing a content analysis methodology, the research delves into the philosophical underpinnings that shape the conceptualization and evolution of OHS as a scientific discipline. The study traces the historical development of human interaction with work, referencing key figures such as Plato, Saint Thomas Aquinas, Darwin, Maslow, and Karl Popper, to build a comprehensive understanding of the epistemological framework governing OHS. The research highlights the recognition of OHS by the International Labor Organization (ILO) in the 1970s, emphasizing the application of Deming's continuous improvement cycle for accident prevention and health protection. This paper argues that epistemology, through knowledge construction, paradigm establishment, and the application of Popper's falsificationism, supports the recognition of OHS Management as a legitimate science. By connecting these epistemological principles with practical approaches to risk management and safety practices, the study provides insights into the interdisciplinary nature of OHS in engineering. The conclusions suggest that OHS Management must be considered a dynamic and evolving science, crucial for ensuring worker safety and organizational health at multiple levels. This interdisciplinary approach links the philosophical with the technical, establishing a strong foundation for future studies and applications in OHS within engineering fields.

INTRODUCTION

This article is the result of doctoral thesis research on the implementation of the occupational safety and health management system in a particular case of construction. During the study of its background, it was imperative to study the epistemological also called philosophy of science in this case to one of the branches of engineering sciences such as the management of safety and health at work, and thus, to identify the inductive method of study. Using the methodology of content analysis, it is possible to obtain the epistemic and disciplinary paradigms from which the researchers, according to their scientific culture, focus the study of their object and the epistemological operators that these provide, in the study Plato, the Thomistic School, Ludwig, Maslow, Popper, among others, will be mentioned.

For this reason, it is important to define the following concepts from the outset:

Occupational health and safety. The set of rules and procedures deals with managing or administrating the risks inherent to the operations and production procedures in the industry, commercial activities, and services. Considering health risks, possible accidents to workers, damage to company property, and environmental impacts. It is very common to find the term HSE, an acronym for Health, Safety, and Environment, about the subject (Cortez, 2011)

Risk management. Risk management is a structured approach to managing uncertainty related to a threat, through a sequence of human activities that include risk assessment, developing strategies to manage the risk, and risk mitigation using management resources. Strategies include transferring the risk to another party, avoiding the risk, reducing the negative effects of the risk, and accepting some or all the consequences of a particular risk (Cortez, 2011)

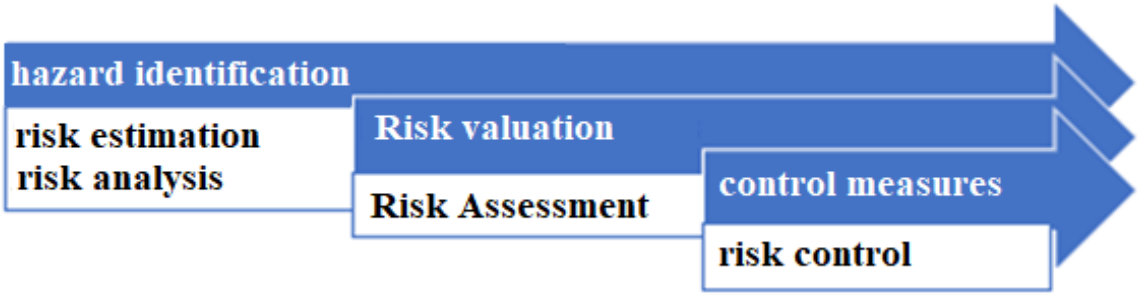

Figure 1: Occupational health and safety risk management

Note: Occupational health and safety. Prepared by: Author of the article

Safety and health at work are linked to the different layers that make up the reality from molecular neurology to cognition, a new field of the discipline known as Neuroscience arises majestically, which allows us to understand what makes us what we are; because it studies the nervous system from a multidisciplinary point of view with the contributions of various disciplines: Biology, Neurology, Psychology, Chemistry, Physics, Pharmacology, and Informatics, in this new conception of the human mind which is the higher mental functions (Lai, 2020) Safety and health at work is related to load modeling that allows to adequately model loads of an electrical system to correctly represent its operation in different studies or applications. The load modeling task comprises mainly two stages: i) the choice of a load model and, ii) the parametric identification of the parameters/constants of the chosen load model; load models are mathematical functions that try to reproduce the real behavior of the loads. These functions have as output variables the active or reactive power. The independent variables are usually: voltage, frequency, and time (Constante & Colomé, 2022).

The evolution, major challenges, theoretical advances, maturation, and success stories that have taken place in the field of automatics education have been documented over the years in numerous articles, reports, and reviews. These challenges have been the subject of debate over time, but many of the most influential papers are little known to the community (Muñoz de la Peña et al,2022) In the epistemological bases, the approaches, and strategies of theoretical and empirical approach, which is reviewed here the determination and analysis of the current state of such production, as a basis for a conception of the quality of higher education that is appropriate in the context of application and fruitful for the development of policies in the academic field, the same that is placed at the service of a conceptual construction located, with relevance and usefulness based on the knowledge of the current academic production on the subject; Therefore, quality has acquired a notorious centrality, relevance, and ubiquity in many areas of contemporary industrialized societies, including higher education (Acevedo et al, 2022)

METHODOLOGY

This research employs the content analysis methodology, which Laurence Bardin defines as "a set of communication analysis techniques aimed at obtaining indicators (quantitative or qualitative) through systematic and objective procedures for describing the content of messages, thereby allowing the inference of knowledge related to the conditions of production and reception within a specific social context" (Constante & Colomé, 2022). Content analysis was selected due to its ability to explore complex theoretical frameworks and extract meaningful insights from both qualitative and quantitative data, which are central to understanding the epistemological underpinnings of Occupational Health and Safety (OHS) Management Systems.

A key aspect of this study was developing a historical awareness of the topic. This required an in-depth review of the historical evolution of epistemological thought in relation to OHS, emphasizing the dynamic nature of philosophical and scientific perspectives across time. As Hans-Georg Gadamer (2007) argues, historical awareness is essential for understanding the relativity of opinions and the contextuality of knowledge. The research traces the development of key epistemological paradigms and their application to risk management and safety within engineering, allowing for a nuanced analysis of the subject.

By utilizing content analysis, the study systematically examines the philosophical constructs and scientific methodologies that have shaped the evolution of OHS. This approach enables the identification of key paradigms and models that inform current practices, ensuring a comprehensive understanding of the subject from both a theoretical and applied perspective.

DEVELOPMENT

The philosopher Jean Piaget defines epistemology as "the study of the passage from states of lesser knowledge to states of more advanced knowledge, asking how the subject knows (how one transitions from one level of knowledge to another); the focus is more on the process rather than on 'what is' knowledge itself" (Gadmer, 2007). This perspective emphasizes the evolution of knowledge and the mechanisms through which it is acquired, rather than its content.

Austrian epistemologist Karl Popper identifies three main characteristics of epistemology:

1. The focus on the validity of knowledge, with the process by which the subject obtains such knowledge being irrelevant to its validity.

2. Science is viewed through the lens of logical language, meaning epistemology deals with scientific statements and their logical relations, allowing for their justification.

3. It possesses a logical-methodological nature, meaning it is normative and philosophical (Camarena, 2012).

In the context of Occupational Health and Safety Management (OHS), epistemology is not limited to the study of this branch of engineering sciences or its historical development. Rather, it is a continuous activity in a dynamic world, where theories of human behavior constantly emerge in the pursuit of self-understanding, happiness, and the confidence of being free from the various dangers found in society and the surrounding environment.

The International Labor Organization (ILO) defines occupational safety and health as the science of anticipating, recognizing, assessing, and controlling hazards arising in or from the workplace that could impair the health and well-being of people (Alli, 2008).

Exploring Epistemology in Occupational Safety and Health Management

The field of Occupational Safety and Health (OSH) Management is inherently multidisciplinary, requiring a comprehensive conceptual analysis of three fundamental concepts: epistemology,

paradigms, and models (Castro et al., 2014). Epistemology examines the methodological relationship in the construction of knowledge, particularly the dynamic between subject and object, the subjective and the objective, the abstract and the concrete, and theory and practice. The application of both quantitative and qualitative methodologies is essential in understanding how work activities relate to the prevention of workplace accidents. This relationship is reflected in the processes of hazard identification and risk assessment, which are foundational for establishing control measures to prevent incidents and accidents in the workplace (Paucar et al., 2022).

A thorough understanding of paradigms is crucial for grasping how they are used, modified, and constructed within OSH management. Given that OSH is a multidisciplinary field, its complexity grows as new production activities and technological control measures emerge (Al-Msary et al., 2023). Consequently, constant feedback and up-to-date information are required for senior management to make informed decisions. The development and implementation of these models stem from scientific and engineering work, designed to address the challenges faced by workers, companies, and the state. These models are shaped by international standards established by the International Labor Organization (ILO), legal frameworks, technical standards, and safe work procedures, providing a theoretical and objective representation of workplace realities.

Plato in his critical period (3 6 9 - 3 6 1 BC.)

He puts forward the first sketches of the Theory of Ideas and Political Theory. It is in this period that the so-called **Intentions** appear:

- **Ethical intention**. It follows Socrates and wants to base virtue on knowledge. The following concepts must be defined: Good, beauty and justice, and Socratic morality (Gomez, 2017)
- **Political intention**. The rulers must be philosophers who are not guided by ambition but by ideals (Ideas).
- **Scientific intention**. Science can only deal with permanent objects, and these must exist, they are Ideas.

Concerning ethics, his research focuses on three points:

- Establish what is the Highest Good on which happiness is centered.
- To know the nature of Virtue as an activity of the soul.
- Study the virtues and classify them according to the different types of souls. Defining the Supreme Good as the proportionate mixture of a mixed life of pleasure and wisdom. To achieve this mixed life, he establishes the following scale of goods.
- Measurement and moderation.
- Proportion, beauty, and perfection.
- Understanding and wisdom.
- Science, art, and right opinion.
- Painless pleasures and pure pleasures.

The scale of goods is shaped according to the triple standard: Measure - Truth - Beauty. These are the notes of GOOD that will result in HAPPINESS (Hernandez,2005)

Thomistic School

Following the Platonic tradition, St. Thomas Aquinas believed that objective knowledge of reality could be attained through cognitive faculties. Aquinas held that the world, created by God's will, consists of corporeal substances, each with a substrate and accidents, allowing knowledge of the natural world through observation and reflection (De Hollanda, 2011).

Key contributions from Aquinas, primarily found in his Summa Theologica, include:

1. **Harmony between Faith and Reason:** Faith and reason complement each other in the search for knowledge.

2. **Theory of Abstraction:** Knowledge begins with sensory experience, with the mind abstracting universal concepts from particular experiences.

3. **Distinction between Natural and Revealed Knowledge:** Natural knowledge comes from reason and observation, while revealed knowledge comes from faith and divine revelation.

4. **Moral Epistemology:** Aquinas linked moral knowledge to practical reason, asserting that reason can discern universal moral principles.

5. **Importance of Experience:** He emphasized the critical role of sensory experience in understanding the world.

6. **Emphasis on Objective Truth:** Aquinas defended the existence of objective, universal truth that aligns with reality and can be known through reason.

7. **Theology as the Queen of Sciences:** While theology is the highest discipline, Aquinas saw philosophy and other sciences as complementary to the pursuit of knowledge.

Aquinas' contributions have significantly impacted both philosophical and theological traditions, continuing to influence epistemology today.

Darwin's Contributions and the Autobiographical Theories of Human Beings

Following the ideas of Plato and the Thomistic School, Charles Darwin (1858), a British naturalist, shifted the anthropocentric view of humans to an evolutionary theory, placing humans on the same level as other living beings. His autobiographical theories of the human being address three main aspects:

1. Religious: Humans possess special dignity.
2. Philosophical:
- Humans are rational, social, free, and moral beings.
- They seek the meaning of life, addressing metaphysical concerns.
3. Social:
- Aristotle linked human rationality with social nature, suggesting that humans live to integrate within communities.
- This poses challenges to individual autonomy, as one's rights or meaning could depend on their belonging to a community.
- Without humans, there is no culture, and without culture, there are no humans (Geertz, 1973).

Ludwig von Bertalanffy and General Systems Theory

In line with the ideas of Plato, the Thomistic School, and autobiographical theories of the human being, Ludwig von Bertalanffy introduced the General Theory of Systems in 1969. This theory explains the interrelationships between the macro-environment and micro-environment, and their impact on human development.

Macro-environment: Comprises external, uncontrollable factors such as demographic, economic, technological, political, legal, social, cultural, and environmental influences (Pinilla, 2010).

Microenvironment: Consists of factors close to the individual, such as family, society, the workplace, education, and professional affiliations, which influence the ability to meet personal needs (Kotler & Armstrong, 2010).

Von Bertalanffy defines a system as a collection of interrelated elements working toward a common goal. His General Systems Theory emphasizes the analysis of the internal interactions of a system’s parts to explain various phenomena in reality. Although initially developed for biology, this theory can be applied to other scientific fields as well.

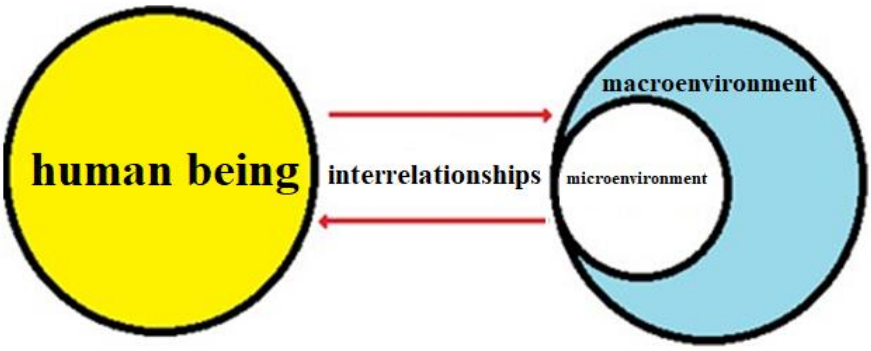

Figure 3: Human Interrelationships with the Macro and Microenvironment

Note: Prepared by the author

General Characteristics of Systems Theory

Ludwig von Bertalanffy's Systems Theory highlights several key principles:

1. **Objective Definition:** A system's designer can define and adjust its objectives as needed.
2. **Globalism:** The whole system is greater than the sum of its parts, meaning changes in one part affect the entire system. (Von Bertalanffy, 1989).
3. Homeostasis: Systems strive to maintain equilibrium despite internal and external changes.
4. **Subsystems:** Each part of a system functions as a subsystem, possessing the characteristics of the main system.
5. **Equifinality:** A living system can reach the same final state from different initial conditions through various paths.

"No matter what process you receive, the result is the same" (Von Bertalanffy, 1989).

Maslow's Pyramid: The Hierarchy of Human Needs

In alignment with the philosophical traditions of Plato, the Thomistic School, and the autobiographical theories of human existence, Ludwig von Bertalanffy and Abraham Maslow introduced groundbreaking theories that diverged from the deterministic views prevalent in the mid-20th century, such as psychoanalysis and behaviorism. While these schools often framed individuals as passive beings molded by their environment, Maslow sought to uncover the elements that lead to human happiness, self-fulfillment, and personal development.

Maslow first presented his hierarchy of needs in his seminal works, "A Theory of Human Motivation" (1943) and "Motivation and Personality". Unlike earlier schools of thought that emphasized dysfunction and reactive behavior, Maslow shifted the focus toward what drives people toward higher levels of satisfaction and achievement (Acosta, 2012).

His contributions to the understanding of security and safety are particularly relevant:

1. **Basic Needs:** At the foundation of Maslow's pyramid are physiological needs, including physical safety. These essential elements, such as financial security, health, and personal safety, form the bedrock of well-being, directly influencing a person's sense of security in everyday life.

2. **Psychological Safety:** Maslow also emphasized the importance of psychological safety, which encompasses emotional stability, order, and life predictability. In the workplace, factors like job security and clear expectations play a crucial role in fostering psychological satisfaction and overall well-being.

3. **Motivation and Work Environment:** According to Maslow, once basic needs are met, individuals strive for higher-order needs such as esteem and self-actualization. A work environment

that prioritizes both physical and psychological safety can fuel motivation, personal growth, and professional development.

4. **Hierarchy of Needs in Organizations:** The application of Maslow's hierarchy in organizational settings prompts considerations such as job security, stress management, and creating environments that address both the physical and emotional needs of employees. These considerations are pivotal for enhancing organizational well-being.

5. **Holistic Approach to Safety:** Maslow's theory calls for a holistic approach to human safety. In the context of occupational safety, this means addressing not only the physical aspects, like accident prevention, but also the emotional and psychological components to ensure a healthy, secure work environment.

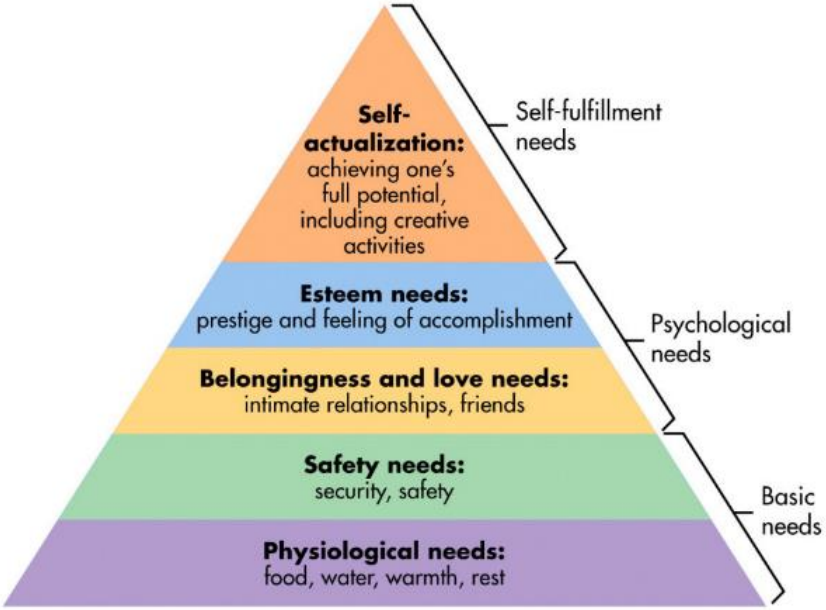

Figure 4: Maslow's Pyramid

Note: Maslow's Pyramid. (Acosta, 2012)

While Maslow did not directly formulate specific theories on occupational safety, his holistic approach and understanding of human needs can guide practices and policies promoting a secure and fulfilling work environment.

Management Paradigms and Their Link to Occupational Safety and Health

Drawing from the ideas of Plato, the Thomistic School, autobiographical theories of human beings, Ludwig Von Bertalanffy, Maslow, and paradigms in risk management and occupational safety (Hernandez, 2005), it is evident that modern organizations require a management approach centered around holistic integration. This paradigm views organizations as open systems where all elements—people, processes, and environments—are interconnected.

The management approach can be structured around three key axes:

1. Internal Elements of Organizations: This includes human resource productivity, machine efficiency, control over work processes, and the alignment of functions and interactions with organizational objectives.
2. Organizational Environment: The organization's interaction with its external environment, considering factors such as technological advancements and how they influence organizational operations and growth.
3. Organizational Projection and Development: This involves long-term strategic planning to meet the needs of various stakeholders, and the creation of systems that support the overall

development and sustainability of the organization. It emphasizes understanding the cultural elements, actors, and systems that shape the organization and its link to the external environment (Hernandez et al., 2007).

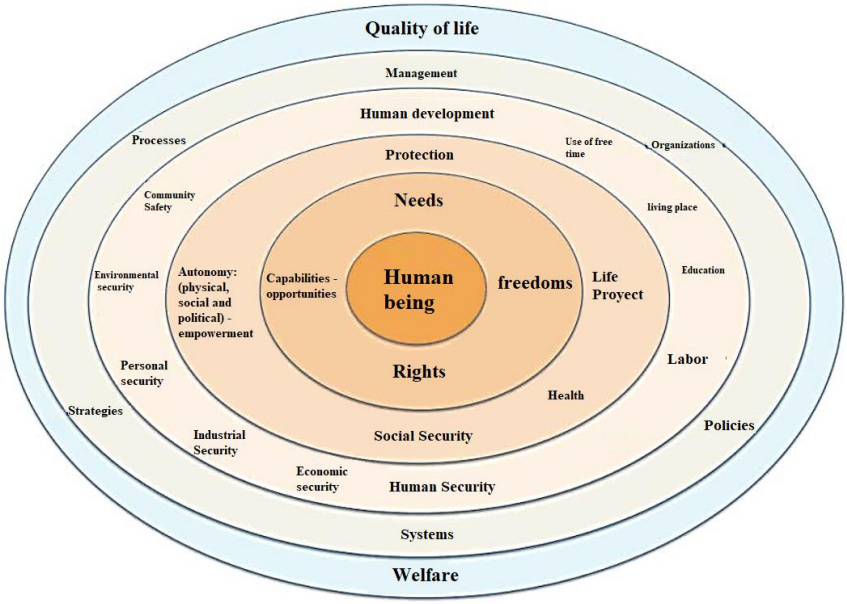

Figure 5: Human beings and their needs

Note: Bases epistemológicas de la gestión de la seguridad social en contextos de violencia, (Rodríguez & Gonzales, 2014).

Karl Popper and Falsificationism

Karl Popper (1902-1994), influenced by social issues after World War I, initially joined the Marxist Socialist Party but later criticized Marxism as dogmatic and pseudo-scientific. Popper advocated that scientific knowledge should not be considered finite, and he emphasized the need for a critical attitude in science. He defended scientific knowledge as a tool for human progress, both materially and ethically, while being a strong critic of totalitarianism and a proponent of an open society grounded in freedom and responsibility.

Popper's concept of falsificationism stands in contrast to positivism, which views science as the pursuit of metaphysical truth. Falsificationism, on the other hand, asserts that science interprets reality through testable hypotheses, emphasizing the deductive method and predictive consequences (Popper, 1980). A statement is considered scientific if it can be proven false through experimentation (Rodríguez & Gonzales, 2014).

Popper's ideas can be applied to occupational safety and health as follows:

1. **Falsifiability and Safety:** Safety approaches should be formulated in ways that allow them to be tested and refuted, ensuring effectiveness.
2. **Empirical Approach:** Safety practices should be based on empirical data, using observations and experiments to validate and improve them.
3. **Iterative Improvement:** Safety programs should evolve through continuous cycles of implementation, assessment, and adjustment based on feedback and results.
4. **Prediction and Prevention:** Predictive capabilities should be used to foresee risks and implement preventive measures before accidents occur.
5. **Responsibility:** Clear communication of risks and safety measures is essential, reflecting the responsibility in ensuring safety protocols are understood.

Deming Cycle

W. Edwards Deming is regarded as one of the most influential figures in process management within companies. Between 1943 and 1945, Deming promoted statistical quality control courses for industry professionals and universities across the United States. In 1950, he lectured senior Japanese managers on the benefits of statistical quality control and conducted a course for 400 Japanese engineers.

Dr. Deming's most significant contribution was his **fourteen principles** for transforming organizational management (Deming, 1989). These principles, seen as a theory or philosophy, help organizations understand how internal processes function and ensure success through quality. These principles assist senior management in assessing decision-making within any product or service organization, helping determine whether they are on the right path to remaining competitive, protecting investors, and maintaining employment.

The **Deming Cycle**, also known as **PDCA** (Plan, Do, Check, Act), is composed of four phases focused on continuous improvement, ensuring companies stay competitive (Bardin, 2002).

Phases of the Deming Cycle

The PDCA cycle consists of the following stages (Moen & Norman, 2009, p.11):

1. **Plan**:
- Identify problems or improvement opportunities.
- Set clear goals and objectives.
- Develop a plan with strategies and resources to address the problem.

2. **Do**:
- Implement the plan.
- Collect data to assess actual performance against the set goals.
- Execute the planned activities.

3. **Check**:
- Analyze data collected during the execution phase.
- Compare results to the goals established in the planning phase.
- Identify significant deviations and investigate underlying causes.

4. **Act**:
- Implement improvements based on the analysis and results.
- Adjust the original plan using feedback and insights gained.
- Prepare for the next cycle of continuous improvement.

This cyclical approach promotes **continuous improvement** in processes and is crucial for **quality management** and **quality assurance**. After the "Act" phase, the process returns to the "Plan" phase, ensuring ongoing adjustments and enhancements.

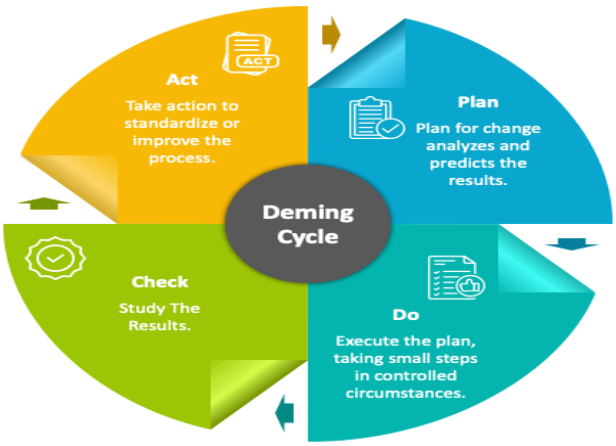

Figure 6: Deming Cycle

Note: Source: https://www.sketchbubble.com/en/presentation-deming-cycle.html

Philosophy of Occupational Health and Safety Management

Occupational Health and Safety Management for Individual Satisfaction through Epistemology

1. **Preventing Human and Material Damage**:
Organizations aim to ensure optimal safety standards to prevent any incidents that could harm workers or damage equipment.

2. **Incident Prevention**:
It is crucial for organizations to avoid any incidents that may lead to material, economic, or human losses.

3. **Raising Safety Awareness**:
Many companies, either through internal policies or legal requirements, implement safety measures to protect their employees. Creating awareness about the importance of using safety equipment and passive protection measures is essential (Popper, 1980). Additionally, conducting safety and health talks is vital for worker education.

4. **Preventing Degradation of Natural Resources**:
Organizations should implement methods that ensure the responsible use of natural resources, with a focus on avoiding their degradation to conserve the environment (Gomez, 2017).

CONCLUSIONS

1. **Epistemology is essential for understanding the development of quantitative methodologies** used in workplace accident prevention, as it relies on the systematic observation of processes and associated risks.

2. **Safety management paradigms evolve alongside workplace hazards**, allowing organizations to adapt their control strategies according to changes in multidisciplinary activities within the work environment.

3. **Popper's criterion of falsifiability facilitates the design of models and control measures**, enabling the assessment and mitigation of risks to which workers are exposed, providing a solid foundation for informed decision-making in accident prevention.

4. **Occupational health and safety management benefits from epistemological analysis** by providing tools to measure the degree of uncertainty and risk in workplace accidents, leading to the implementation of more effective preventive measures and improved workplace safety.

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