A Hazard Recognition Training Intervention for Steel Manufacturing Workers and Supervisors

Authors

Luz S. Marín, Associate Professor, Department of Safety Sciences and Environmental Engineering, Indiana University of Pennsylvania, Indiana, Pa., USA
luz.marin@iup.edu

Majed Zreiqat, Professor, Department of Safety Sciences and Environmental Engineering, Indiana University of Pennsylvania, Indiana, Pa., USA
zreiqat@iup.edu

Wanda Minnick, Professor, Department of Safety Sciences and Environmental Engineering, Indiana University of Pennsylvania, Indiana, Pa., USA
wanda.minnick@iup.edu

Chloe Croft, Undergraduate Student, Department of Safety Sciences and Environmental Engineering, Indiana University of Pennsylvania, Indiana, Pa., USA

Brooke Endress, Undergraduate Student, Department of Safety Sciences and Environmental Engineering, Indiana University of Pennsylvania, Indiana, Pa., USA

Julia Robins, Undergraduate Student, Department of Biology, Indiana University of Pennsylvania, Indiana, Pa., USA

This paper was presented at AISTech 2024 — The Iron & Steel Technology Conference and Exposition, Columbus, Ohio, USA, and published in the AISTech 2024 Conference Proceedings.

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Hazards are ever-present in the steel plant environment, and a heightened awareness and emphasis on safety is a necessary priority for our industry. This monthly column, coordinated by members of the AIST Safety & Health Technology Committee, focuses on procedures and practices to promote a safe working environment for everyone.

Employee training is recognized to be a key element in the occupational safety and health management systems that directly influence workers' behaviors and the safety of work environments. Education and training are highlighted as important elements for informing workers and managers about workplace hazards and controls as an Occupational Safety and Health Administration (OSHA) recommended practice. Additionally, it provides workers with a greater understanding of the safety and health program and how they can contribute to its development and implementation.

The overall research objective of this study was to develop and test a customized training strategy for hazard recognition in the steel industry wiwith the aim to disrupt the pathway to occupational injury/illness. This article presents the current results of the initial aims of the study. First, to conduct a literature review to identify best practices in hazard recognition in the steel industry and other industry sectors. Second, aim consisted of interviews with key personnel in the steel industry to evaluate the effectiveness of the current safety training programs and was qualitative in nature. Plant managers from three facilities of a large steel manufacturing organization in the Northeastern U.S. were interviewed to examine their perception of workplace risk factors and the effectiveness of their safety training programs. Safety hazards identified included moving parts, overhead crane movement, and ergonomic-related hazards, as well as health hazards of noise, heat stress, and chemical exposure. Result indicated that despite its perceived effectiveness, the quality of training could be improved with more focus on hazard awareness and recognition, customized training by location, making it more hands-on and interactive, and training programs for the trainers.

Introduction

In any activity, the risk of getting injured derives from the hazards associated with the context of the activity, including tools, materials, equipment, work procedures, internal and external conditions, work organization, and even other people sharing the work environment.

In 2022, the metal U.S. manufacturing industry (NAICS 331) reported 23 work-related fatal injuries showing an increased trend from 2019 where only 17 fatalities were reported.[1] Additionally, the steel industry reported in 2022 a 3.6 incident rate of non-fatal occupational injuries per 100 full-time workers and a 30.3 total recordable illnesses incidence rate per 10,000 full-time workers. Moreover, the number of nonfatal occupational injuries and illnesses involving days away from work (DAFW) was 8,940; restricted

activity (DART) was 17,670; and job transfer (DJTR) was 8,740. The top leading exposures during that period included contact with object or equipment (n=15,530; 43%), overexertion (n=10,100; 29%), and fall, slips and trips (n=5,200; 15%). Most of these nonfatal events resulted in sprains, strains, tears, and fractures (n=4,420; 13%), and cuts, lacerations, and punctures (n=4,320; 12%). Additionally, 460 amputations, 140 chemical burns and 300 cases of carpal tunnel syndrome were reported. Regarding nonfatal occupational illnesses, hearing loss, respiratory conditions and skin diseases continue to rank at the top.

Many safety- and health-related hazards are involved in processes conducted in the steel manufacturing industry. The International Labour Organization's (ILO) in its "Code practice on safety and health in the iron and steel industry" details a list of 27 hazards associated with steel production including slips, trips, falls, falls from heights, unguarded machinery, confined spaces, moving machinery and lack of training.[2] Some of the hazards listed by the ILO are also the top five causes of lost-time injury in 2022, reported by the World Steel Association (WSA), including slip, trip, and fall, the use of manual tools, moving machinery, product handling, and falling from heights.[3] They also reported that the total recordable injury frequency rates (TRIFR) are trending downward from 3.66 in 2021 to 2.82 in 2022 for the global steel industry. Likewise, worldwide reported fatalities decreased by 21%, with 116 fatalities being reported in 2021 and 90 in 2022.

Although there are some slight reductions in these trends, the steel industry still experiences high fatal and nonfatal injury rates when compared to other high-risk industries such as construction or transportation. Work-related injuries and illnesses represent a significant economic burden for the workers and their families, businesses and society overall. Modifying these trends downward requires an in-depth understanding of the injury pathway to address causal factors through systematic prevention strategies to minimize risk levels. Significant research efforts in the field of occupational safety and health have been devoted to understanding the injury pathway to conduct early interventions in their precursors.

The previous study done by Indiana University of Pennsylvania in the steel industry indicated that when operators perceive a positive safety climate, they are less likely to underestimate the risk attributed to hazards present in the workplace. In that study, steelworkers evaluated were more likely[35] to identify safety-related hazards (e.g., contact with objects/equipment, falling hazard) than health-related hazards (e.g., fumes, metal dust, noise or ergonomics-related risk factors). This discrepancy in hazard recognition (safety versus health) is expected since the workplace focus is generally on minimizing the exposure to conditions with immediate potential of causing harm rather than on those with delayed consequences such as health-related hazards (e.g., occupational diseases). The authors highlighted that finding is problematic since workers could underestimate the risk associated with unidentified health-related hazards, reducing their awareness and protection against them because they believe that it is not going to happen to them or do not recognize the delayed potential.

Safety Training Interventions

Safety training is an element in safety and health management systems focusing on helping all levels in organizations (managers, supervisors and workers) to develop the knowledge, skills and attitudes needed to perform a job efficiently and safely.[4] Since deficiencies in safety training cannot be considered as a root cause in the injury pathway, training is complementary in enhancing the effectiveness of other controls implemented, which in turn can minimize the likelihood of workplace injuries and illnesses. Thus, employee training is recognized to be a key element in occupational safety and health management systems with a direct influence on workers' behaviors and safer work environments.[5–9]

When administrated periodically and systematically, safety education and training is recognized as a vital factor of a successful safety program.[10] Although safety training may increase the reporting of injuries and illnesses,[11] some studies have reported positive effects on reducing the severity of certain events.[11] In contrast, lack of or inappropriate safety training is suggested as a contributing factor in the injury pathway.[12] Safety training interventions have shown effectiveness in reducing injuries,[13] enhancing self-efficacy,[14] modifying risk perceptions[15] and influencing safety practices.[16]

Education and training are part of the overarching safety management systems framework established in ANSI Z-10 (2019) and ISO 45001 (2018). In 2016, OSHA included safety education and training in its "Recommended Practices for Safety and Health Programs." In these recommended practices, education and training is highlighted as an important element for informing workers and managers about workplace hazards and controls as well as providing them with a greater understanding of the safety and health program and how they can contribute to its development and implementation.[4] In the NIOSH hierarchy of controls, education and training is considered an administrative control; however, it remains a priority on the National Occupational Research Agendas (NORA) for nearly every industry sector, signifying that researchers in the field of occupational safety and health support continued investment in the development and delivery of effective training material.

The overall research objective of this study was to develop a customized training strategy for hazard recognition in the steel industry for both workers and supervisors with the aim of disrupting potential root causes of the occupational injury/illness pathway. The

proceeding presents the current results of the initial aims of the study, including:

- Conducting a literature review to identify best practices in hazard recognition in the steel industry and other industry sectors.
- Conducting a qualitative analysis through interviews with key personnel in the steel industry to evaluate the effectiveness of the current safety training programs.

Safety Training Effectiveness

Safety training is delivered in the workplace as an essential element to enhance workers' abilities to recognize and properly mitigate hazards associated with routine and non-routine activities.[17] Effectiveness in training refers to the impact that the training process should have on learning transfer and competency.[18] The effectiveness of the safety training interventions has been posited mainly on positively affecting worker practices such as their ability to interpret and implement safety procedures, properly apply safety measures in real-life situations, gauge the risk associated with workplace tasks, promote worker participation, and foster a positive safety culture.[19,20] Subsequently, the effectiveness of a safety training intervention has been associated with factors such as delivery method, participants level of engagement and applicability of the information received. Additional factors include the identification of trainees' personal benefit or motivation to engage in the training, along with materials and content that carefully consider the specific needs and characteristics of the trainees.[19,20]

Training Instructional Design and Delivery Methods

In terms of the delivery method, training design should incorporate adult learning principles, use a systematic approach and consider active learning strategies. The andragogical model proposed by Knowles (1968) provides guiding principles on how to provide education or training to adults as opposed to pedagogy (education of children).[21] Andragogy includes six principles about learning which should be considered in delivering safety training: self-concept, accumulated experiences, readiness to learn, orientation to learn, motivation and need to know. In developing these principles, Knowles highlighted that adult learners are motivated to learn when they see the immediate relevance and application of the connection to one or multiple aspects of their lives since adults' ability to engage in new information is influenced by their life experiences. These characteristics are highly relevant to safety and health training and the aim of enhancing workers' safety knowledge, skills and attitudes.

The first principle — self-concept — states that adults need to know why the learning event is needed prior to committing to learning it. Therefore, Knowles suggests that training facilitators must help learners realize "why" they need to know. The learner's self-concept is related to the fact that the adult student no longer wants to be "dependent" and will resist situations that feel forced. In this scenario, the training facilitator must prioritize in designing more self-directed elements into the training, such as providing choices or encouraging decision-making. The role of accumulated experience recognizes that adults come to learning events with many various backgrounds, work roles, learning preferences and previous, both positive and negative, training encounters. By designing training that acknowledges these differences and encourages adult participation, facilitators create an environment where shared experiences enhance learning. Readiness to learn means that adults are "ready now" to learn the information because there is a clear benefit and/or near-immediate value in doing so. Training designers need to commend the readiness to learn and reward it with material that is informative, clear and useful to "real" workplace scenarios. Orientation to learning is the shift from learning about a topic to solving problems related to that particular theme. Training designers should provide elements of problem-solving throughout regardless if the material is addressing introductory or advanced levels.

Finally, motivation,[36,37] the last of the six principles, refers to intrinsic rather than external factors, such as self-esteem, personal goals and sense of achievement. When considering motivation, training designers can consider fostering an "emotional" presence in the training environment that capitalizes on those motivational factors.

Adult learning principles[38,39] should also be incorporated in the creation, organization and delivery of training content to customize learning experiences and environments. The learning model provides guidance for instructional design and includes the elements Analysis, Design, Develop, Implementation and Evaluation (ADDIE). The analysis portion refers to conducting an examination of the "need" for training by considering the audience baseline knowledge level and learning what additional knowledge would be useful for them. It should be noted that individuals within the audience are at different levels, therefore it may be appropriate to consider a variety of learning goals and levels that students can choose to achieve. The design aspect considers specific learning objectives and a clear sequence of learning strategies that will help meet those objectives. Researchers have concluded that developing training material that incorporates active learning strategies, such as learning by doing, discovering, collaborating, problem-solving and reflecting, offers a greater learning value to the student and potentially greater learning transfer.[22–25]

The ADDIE model suggests that the developed training material should be piloted for feedback and improvement prior to the next phase.[24,26] Implementing training requires thinking about the "space" in which

Table 1

Integration of Knowles' Principles of Adult Learning and ADDIE Instructional Design Model

	Need to know	Self-concept	Accumulated experiences	Readiness to learn	Orientation to learning	Motivation
Analysis	Determine learners' reasons for engaging in the learning experience and their expectations	Design learning experiences that empower them to take ownership of their learning journey	Incorporate their prior knowledge and experiences into the learning process	Identify learners' motivations and interests in the training topic and align them with their applicability to their work environments	Design activities that focus on workplace applications and problem-solving	Design learning experiences that capitalize on learners' intrinsic and extrinsic motivational factors
Design	Explain how the content will help them achieve their goals and address their needs	Create training materials and activities that allow participants self-directed learning and decision-making, reflecting adults' desire for autonomy	Develop learning activities that encourage learners to draw upon their past experiences to make connections and apply new knowledge	Design learning experiences to learners' readiness levels and interests, providing challenges and opportunities for growth	Develop learning materials and activities that encourage active participation and engagement	Incorporate strategies such as goal setting, feedback and recognition into the learning process
Development	Develop resources and activities that provide explanations and examples that illustrate the practical relevance of the content	Develop resources that foster learners' sense of responsibility for their own learning	Create opportunities for learners to share their experiences with others and learn from each other's perspectives	Develop resources and activities that support learners' readiness to learn	Create opportunities for learners to apply concepts to workplace situations	Develop resources and activities that provide opportunities for learners to take ownership of their learning and pursue their interests
Implementation	Provide opportunities for learners to explore topics of personal interest within the learning context	Provide opportunities for learners to set their learning goals and monitor their progress	Facilitate discussions and activities that allow learners to relate new concepts to their existing experiences	Offer chances for learners to explore topics of personal interest within the learning context, fostering curiosity and engagement	Provide support and guidance as learners engage in hands-on activities and problem-solving tasks	Create a supportive learning environment that fosters motivation and engagement
Evaluation	Assess learners' satisfaction and perceived value of the learning experience	Assess learners' ability to take responsibility for their learning outcomes and make informed decisions about their learning process	Assess learners' ability to apply their prior knowledge and experiences to new situations and problems	Measure learners' engagement and motivation throughout the learning process	Assess learners' ability to transfer learning to work environment contexts and solve practical problems effectively	Measure learners' motivation levels and the impact on learning outcomes

the training will be delivered, the time of day, the temperature of the room, the arrangement of working surfaces as well as differing degrees of delivery techniques. It also includes items like how students will enroll in the class and providing them with information on how to prepare for the class. Lastly, a formative evaluation at the end of the training event to determine if certain skill sets were obtained and the overall perception of satisfaction should be assessed.[27] By integrating Knowles' principles of adult learning into each phase of the ADDIE model, instructional designers can create learning experiences that are tailored to the unique needs, preferences, and characteristics of adult learners, resulting in more engaging, relevant and effective educational programs. Table 1 summarizes the main proposed aspects of this integration.

Methods

Study Design and Participants.

The study used a cross-sectional design with a convenience sample of plant safety managers from three facilities of a large steel manufacturing organization in the Northeast of the U.S. Prior to conducting the interviews, the research team contacted the managers to discuss the scope of the study and the interview settings. Participants were informed that the interview questions were targeting their own perceptions regarding the safety training program in the facility. No compensation was provided for participating in the interview. Procedures and methods conducted in this study were approved by the university's Institutional Review Board (IRB) prior to data collection.

Measure Instruments

The interviews were conducted online through Zoom and lasted between 30 to 60 minutes depending on the interviewee's availability and willingness to expand on each question. The interviews were recorded to allow the research team the opportunity to go back and listen to the recordings. Notes were also taken to support recording and data collection. Prior to recording the sessions, participants' consent to record was sought. Since the way the questions were asked may affect the quality and extent of collected data, the interviews were semistructured to make sure the interviewees provided as much data as possible. Participants were informed of the confidentiality of the information collected and they were allowed to talk freely with no constraints. Open, semistructured interviews are conducted with the researchers asking a question, the interviewee talking on that topic, and then exploring further, through follow-up questions.[28] This interview style provides opportunities for the interviewer and interviewee to discuss some topics in more detail. The interview questions focused on safety climate, risk perception, workplace hazards and training content.

The first set of questions were demographic related including job title, years of experience and prior experience, if any, in the steel manufacturing industry. The next set of questions focused on management perceptions of safety and risk at the management and co-workers' levels. Examples of questions asked included:

- What are the major hazards in the workplace?
- What hazards are you most concerned about?
- How effective are the current controls in preventing and controlling the hazards?

The last set of questions focused on training content and effectiveness. Questions asked were:

- Please describe the training content at your workplace.
- How do you evaluate the training provided at your workplace?
- In your opinion, what do you believe is missing from your current training?
- If you were to add to the training content, what would you add?
- Which main topics would you add to the training?
- Overall, how do you rate the training in terms of its effectiveness and content?
- What recommendations would you make to improve the training?

Data Analysis

Interview recordings were analyzed using content analysis based on major hazards and safety concerns, training quality, risk perception, training topics, and training perceived gaps. The interviews were coded independently by three research assistants. Then, all the qualitative data was aggregated to identify all the topics discussed by the participants.

Results

Participants Demographics

A total of five interviews were conducted with plant managers and safety managers. The interviewees were experienced managers in the steel industry; they have obtained graduate degrees; they have on average 22 years of seniority within their company; and they have served as plant managers for at least 9.5 years. They have in-depth knowledge of the plant operating procedures and the safety training provided to new hires and other workers.

Hazard Identification

When asked about the major hazards, management participants perceived safety hazards as their major concerns. The four major safety, health and human-related

Table 2

Hazard (Condition, Situation, Behavior) Identification by Safety-Related and Health-Related Categories

Safety Hazards	Examples
Ergonomics-related hazards	Welding steel sheets, overreaching, bending, twisting, lifting heavy material (manual material handling like coils and sheets) and repetitiveness
Open moving parts or improperly guarded	Air knives, rollers, moving strip
Crane movement/overhead work	Overhead cranes
Obstacles (tripping-related hazards)	Improper tool storage, housekeeping issues, steel rolls
Health hazards	**Examples**
Noise	Air knives, motors, and rolls
Heat stress	Molten zinc pot
Chemical exposure	Chemical splashing: zinc, hexavalent chromium
Fire-related hazards	Chemicals like hydrogen and metals
Cognitive and organization-related hazards	**Examples**
Non-routine task	Training is not site specific
Gap in what is being taught vs. what they do at the production floor	Hazard identification and recognition
Worker's awareness of hazards	Walking on an uneven surface
Workers' awareness of their surrounding	Moving parts, hot environment, etc.
Underestimating the risk	Improper use of personal protective equipment (PPE) and follow workplace procedures
Contractors' safety	—

hazards are presented in Table 2. As to safety-related hazards, ergonomic-related hazards (lifting and moving heavy material, overreach, bending, pushing, and positioning), open moving parts (i.e., air knives and rolls) and overhead crane movement were the most concerning. Health hazards were less concerning with noise and heat stress being identified as the top two health hazards. Human-related hazards including hazard recognition and awareness were a major concern as well.

When asked about current training in place, participants stated that the training overall is somewhat effective, however there is always room for improvement. The training was reported to be a three-day training for new hire which contains PowerPoint Presentations and safety videos. Additionally, the training has a walkthrough tour at the end. Despite its perceived effectiveness, training could be improved with more focus on hazard awareness and recognition, customized training by location, enhancing the training quality by making it more hands-on and interactive, and training the trainer. Training pros and cons are summarized in Table 3 with proposed recommendations for improvement.

Table 4 summarizes the major current controls in place. Participants stressed on the importance and effectiveness of the "20-foot initiative" to avoid moving parts, the "2-minute drill" to talk about out of the ordinary experienced situations and safety related issues, "task selectively" where new hires start with easy tasks and progress over time with experiences. Additional controls included monthly meetings, air quality monitoring, and

Table 3

Training Effectiveness and Proposed Improvements

Training pros	Training cons	Recommendations
New hire training/ orientation	More informal than formal/long new hire training (3-day training)	Hazard awareness and recognition/proper evaluation of training effectiveness/trainees' feedback
Safety videos/Show real footage of incidents in the trainings	Not site or location specific/gap in what is being taught vs. what they do at the production floor	Interactive training: Active and hands-on training
New employees are assigned a mentor to coach and assist them	Mentors and supervisors are not properly trained/lack of safety department involvement after the new hire orientation	Task-specific training/train the trainer/one-on-one safety discussions
Job safety analysis (JSAs)	Reading JSAs prior to training	Train first and then read JSAs. JSAs are not training.
Occupational nurse on-site trains on ergonomics	Simple training, not thorough/only office ergonomics video	More work-related ergonomic training
Refresher training	Not site specific/watched independently/no formal assessment	Specialized training per location/training monitoring/ tracking

color coding of hardhats to differentiate between new and tenured workers.

Discussion

Employees' perceptions of workplace safety differ based on demographic characteristics (e.g., age, genders, education level, ethnicity, etc.) and employment factors such as job title and job responsibilities or seniority.[29–31] The preliminary qualitative data showed that steel plant managers identified several safety hazards but also they were knowledgeable of health hazards such as noise, heat stress, or chemical exposure, which were barely identified by workers surveyed in other previous studies. This difference in safety perception by job title is relevant since,[35] to implement effective risk management, it is central that all manager and employees identify hazards, but as well as reach a minimum agreement on the impact on workplace safety and health.[32] A broader hazard identification among managers is beneficial since they have power and authority to address them.

In contrast, the lack of awareness of these differences in hazard identification may lead managers to assume their subordinates have sufficient knowledge about the workplace conditions and mislead training efforts. These results highlight the importance of customizing training to the needs of employees by every level in the organization including supervisors and managers.[4,33]

Managers were also able to identify gaps in the effectiveness of the training program mainly in aspects related to the specific skills needed to perform certain tasks and in the potential deficiencies in delivery methods. The negative effects of integrating safety training as a supporting element in hazard control have been widely documented in the scientific safety literature. The literature review showed that although effective training is key to maintaining high quality employees and a high level of safety, it is still delivered without a comprehensive evaluation of its impact on safety performance and productivity. Regular evaluation of the impact of a training program based only on hours trained, number of workers covered, or workers' ability to remember the training content immediately after its delivery reduces the opportunities to evaluate the actual effectiveness of a training program.[34] That reduction could be observed also as an indicator of the importance given to training by the upper management. Conducting a thorough assessment of the workplace to identify potential hazards and risks both safety-related and health-related is a core factor in designing a training program that not only responds to the workers' needs, but also to the business goals. Effective training also requires that organizations change their perception of employees as passive recipients of information into active participants that require training content relevant and specific to their roles and responsibilities. Motivation is a key element in adults' learning, however workers that are treated

as passive actors may become demotivated and disinterested in the training process resulting in workers' difficulties to develop the required knowledge, skills and abilities to perform their jobs safely and effectively. Delivery methods created mainly on passive training approaches may limit workers' sense of ownership and responsibility on their own learning. Incorporating the adult's learning principles proposed by Knowles into the ADDIE model for instructional design will help involve workers in their learning process, encourage participation, and provide more opportunities to build skills that they can apply not only in the day-to-day regular work situations, but also in non-routine situations that require applied critical thinking abilities for immediate actions.

Conclusions

Proper and effective safety training is an essential instrument in the protection of the workers' health and safety. Insufficient safety training, or the total lack of it, is commonly identified as an intermediary root cause of an event, or at least a significant contributing factor, which prompts the necessity to conduct a workplace incident investigation. Best practices commonly recommended in the field of safety and health suggest that a systematic approach can identify training needs and tailor the training content considering adult's learning principles as key factors in achieving training goals to enhance workers' knowledge, skills and abilities.

Table 4

Current Controls in Place

Controls in place	Explanation
2-minute drill	When they have out-of-ordinary experience, they take 2 minutes to explain it and its safety to everyone
Task selectivity	New hires start with easy tasks and move up as they progress
Chemical handling videos	Safety videos on proper chemical handling and PPE use
Differentiate new employees from experienced based on their hardhat color	Color-coded hardhats based on tenure/work experience
PPE enforcement	Earplugs and earmuffs for noise hazard. Nitrile gloves for chemical handling and jacket and face shields for chemical splash.
Monthly safety videos	New safety videos that come on monthly basis
Crew safety mentor	Using experienced workers to mentor new hire
Monthly meetings	Decided by corporate and the safety coordinators based on near misses and past accidents on the job
Use of robots	For heavy and repetitive tasks

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