A New Training Strategy:

Design the Work Environment for Continuous Learning

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In the industrial workplace, few people begin a job fully trained. Even when people have prior work experience, they will still need to learn the many nuances of the new work environment that impact one's ability to perform effectively. Furthermore, with the current high rate of change in organization and technology, nearly everyone needs to acquire new competencies to meet the demands of the work environment. As a consequence, all organizations have to educate and train staff to raise their level of performance. This may be achieved by providing new and relevant knowledge and information, by providing hands on experiences, or by cultivating specific attitudes, values and motives.

The human performance demands in the industrial process control environment challenge current training strategies and methods. A new paradigm is needed that closely couples training and job activities situated in the everyday work environment (Bullemer and Nimmo, 1996).

The purpose of training is to develop task appropriate competencies in form of specific knowledge and skills. Most importantly, when people are interacting with large complex systems like those in the process control industry, the system's structure and behaviors change continuously for a variety of reasons. Consequently, it is important that the competencies of the work force keep a breast of the changing demands of this complex work environment.

For example, the production operator is the employee who uses process safety information, safe work practices, and operating procedures to operate and maintain process plant equipment. Today's production operator must be competent in more than the technical aspects of operating and maintaining plant equipment, machinery and controls. (For a full list of the range of competencies see Industry Report 1996 - 1997; Pankoff, 1997)

A good training program differentiates the way in which people work but should provide a standardization of approach. Good training can and should (Furnham, 1997):

- be a focus for aligning the workforce with the company strategy
- ensure that workforce skill levels are up to national or industry standards

- be a powerful individual motivator
- be a good catalyst for change
- be an arena for providing a link between the individual and the company values

Our assessment of current training practices concludes that many of today's industrial training programs fall short of these qualities of a good training program (Bullemer and Nimmo, 1996). Quite by accident, the most influential training is on-the-job training, sporadic, informal and unmeasured as it tends to be. The interactions between people, plant equipment, processes and organizational entities that occur within the everyday work environment have a stronger impact on an operations team performance than any existing training program. The work environment is the primary learning environment. Unfortunately, plant personnel typically do not perceive the work environment as the primary learning environment.

As a new strategy for training, we propose that plant personnel design the work environment to be a continuous learning environment. Following a brief summary of current training practices, we present key dimensions for continuous learning in terms of culture, organization, and workspace design. Explicit design of the work environment along desirable areas of these dimensions will lead to greater job satisfaction, increased plant reliability, better operational integrity and most importantly, and improved plant profits.

Assessment of Current Practices

The National Institute of Occupational Safety and Health (NIOSH) recently published a study that found that traditional modes of employee training involving seminars, posters and videos often fail because they miss the integral human factors that ultimately influence behavior at the worksite. Regardless of a person's knowledge and competency in a particular area, performance depends on motivational considerations like cost and rewards, self-esteem, confidence and conformity pressure.

Use of Traditional Methods

As we seek to enhance or replace these traditional methods, we need to understand the strengths and weaknesses of these techniques.

Heritage. Industrial manufacturing has a rich heritage.Inhe last 10 years training of productions operators has evolved due to changing environmental and regularity requirements. As the main catalyst for change, these requirements have introduced a significant improvement in some areas of training such as process safety management and environmental. The training has resulted in more planned, structured, and documented performance based solutions.

Citations. Some of today's training challenges are highlighted by OSHA and EPA citations. The citations highlight weakness in existing practices. Training violations comprise about 10 percent of total plant safety management (PSM) citations.Initial training is the number one offense, followed by refresher training and lack of employee participation in determining the frequency of refresher training, and finally lack of adequate training records. Measuring the adequacy of training has been identified as a tough issue to solve..

Curriculum. It is important that an organization have a structured curriculum that the new employee and the seasoned employee can measure their progress and achievements. Most companies are challenged to deliver this function as they no longer have dedicated trainers concentrating on this topic. Before the development of a curriculum a company needs to complete a needs assessment which will include competency evaluation. This task can be done with the aid of training consultants who themselves are competent in the best practices in this area. Good consultants are familiar with industrial training initiatives such as the new recruiting philosophy being adopted whereby a company will only employoperators who have completed an industrial foundation training diploma or two year associate degree offered by a local community training college. This means that the company will need to be in partnership with the community colleges to ensure that their needs are being addressed in the foundation training.

Benchmarking. More than 58% of refineries, 57% of petrochemicals, and 36% of chemicals companies do some form of benchmarking of their operator training practices.. Benchmarking is a comparative analysis of what others are doing in production operator training. It allows companies to find the best practices throughout their industry. to help them improve their own practices.

Common practices. Surveys have been done by many different groups to identify the most successful operating training practices as identified by the end users. These surveys illustrate slight differences between different industrial groups within the chemical process. Some common methods that are successful across all groups include (Pankoff, 1997):

- On-the -job training using procedures and training manuals with introductory classes
- Written training manuals for each job with SOPs to enhance written information
- Peer to peer training and qualification
- Computer Based Training (CBT) applications and other self-directed courses

Balancing Methods. Successful training practices identify an effective balance of training methods (Pankoff, 1997). Within the refineries training area, initial training is typically evenly balanced between classroom and field training techniques. Specific job training uses more field training (75%) relative to classroom (25%). In general, companies reviewing training practices of other organizations need to make sure there is an appropriate fit to their operations. Each type of training has its place. Each plant has different conditions that determine the best type of training for their situation. Some factors that influence the selection of type of training include:

- Number of operators to be trained in a given time frame

- Funds available for training
- Availability of training media and materials
- Availability of trained trainers
- Work schedule
- Availability of overtime
- Turnarounds and vacation schedules
- Staffing

Use of Training Program Components

We conducted an assessment of training practices during investigations of twelve petrochemical plants in North America and Europe. We summarized our findings in terms of three important components of an effective training program (See detailed summary of these findings in Bullemer and Nimmo, 1996).

Training needs assessment. Training needs assessment is critical to developing an effective training program. We did not find any formal or systematic methods being used. Moreover, we observed extremely weak practices in assessing individual or team job performance. Assessment of performance enables an organization to understand areas for improving competency levels. Consequently, these organizations had a extremely limited ability to design training programs that addressed specific individual or team competency development needs.

Training development and delivery. Current training development and delivery practices were a ubiquitous concern among all plant personnel. The apprenticeship training emphasized informal "hands-on" and "on-the-job" training. We found significant organizational obstacles to effective on-the -job learning. For many companies, the organizational factors such as work schedule, staffing, availability of trainers, and availability of materials had a negative impact on effective training program execution. We observed strong initial training for field operators, moderate training for console operators, and weak training for all other operations staff.

Training program evaluation. The evaluation of training effectiveness is the final stage of developing an effective training program. The evaluation findings were similar to those of needs assessment. We did not find formal or systematic methods being used. The limited training evaluation that was observed, tended to focus on short term effects of the hands-on training. In general, training specialists did not know the impact of their training programs on the effectiveness of individuals or operations teams.

Dimensions of Continuous Learning

An examination of the dimensions of continuous learning illustrates how specific aspects of the work environment influence day-to-day activities that can have either a positive or negative influence on operational performance. Specifically, we discuss aspects of the work environment in terms of culture, organization and workspace design. Learning is defined as the acquisition of operative knowledge and skills needed to effectively operate the plant as a collaborative workforce. We use the term continuous to emphasize the fact that people are constantly learning about acquiring operational knowledge and skill while they perform their day-to-day activities. Understanding these dimensions of learning is a critical first step to rethinking the operator training strategy.

Culture

Organizational culture consists of the set of values and beliefs that either explicitly or implicitly determine the acceptable behaviors of a group of people (McKenna, 1994). These values are frequently passed on to new members through war stories, rules and actions of veteran members of the group. Organizational cultures exist at many levels within an enterprise. For example, cultures exist at the level of a refinery with subcultures at level of operations teams within a specific process unit of a refinery. The operations team cultures are the most influential in teaching new employees the acceptable operational behaviors for a particular process unit. To the extent that a site management team treats all operations teams the same, there will be some common cultural themes across the operations teams within a site.

There are a number of ways to develop a culture. From the perspective of establishing a continuous learning organization, it is important to identify the important norms and desired behaviors. In this section, we discuss three types of behaviors that determine the kind of continuous learning culture that exists in the operations work environment. These three types are not intended to be a comprehensive set of cultural factors rather they represent key examples pertanent to thepetrochemical plant environment.

Once all levels of the organization have agreed on the desired behaviors, the organizational structures and processes need to be established to develop and reinforce the culture. Moreover, the kind of continuous learning culture that exists has a significant impact of the operational effectiveness of the group.

Policy Compliance

The level of compliance of work groups to published guidelines and policies indicates the level of uniformity of operations practices. Does everyone have their own way of doing things? Lack of compliance may be a sign that published guidelines and policies are out of date and ineffective. Unknowingly, the culture may be teaching individuals to figure out ways of operating that fit the company needs or match individual’s preferences.

Do as I do. We have observed work groups that accept behaviors that deviate from published guidelines and policies. We have characterized this type of culture as “Do as I do, not as it (policy) says." It is extremely difficult to eliminate this culture through management decrees. The experienced individuals of the work are mentoring others to do it the way they do it because it is a better or more convenient way.

Do as we say. We have also observed work groups that do not accept behavior that deviates from plant guidelines and policies. There is usually strong leadership within the work groups to achieve compliance with stated policies and procedures. There is also a tendency for these groups to work hard at establishing acceptable, usable guidelines and policies. In this culture, there is more openness in evaluating the adequacy of the published practices. Consequently, if something is not working, the organization is better able to learn about the limitations and weaknesses of its practices.

Operating Posture

The operators of a process plant with a supervisory control responsibility must be prepared to identify, interpret and respond to process disturbances that impact the performance of the process equipment and automated control system. We use the term posture to characterize the specific attitude operators manifest in the performance of these duties. While individual operators assume different attitudes, the operations team culture tends to promote a dominate posture. Moreover, the dominate posture influences the general level of understanding and competency in preventing and responding to process disturbances.

Reactive stance. In reactive operations, we observe operators waiting for nothing to happen. Operators engage in performing routine activities and wait for the alarm system to alert them to the existence of abnormal condition. When abnormal situations occur, these individuals go into the proverbial "fire fighting" mode. They must quickly come up to speed on what's been happening in the process, identify the location of the disturbance and compensate to bring the process to a stable state. When the process is stabilized, they begin to investigate the root cause of the disturbance. After the operations are normalized, they resume their posture with their back to the monitors waiting for the next alerts. In this type of culture, individuals have difficulty in just maintaining their operative knowledge, much less extending it. Often this type of posture is compensated for by adding more and more pre-alarms or alerts to support the reactive operations. An abuse of the alarm system becomes an unfortunate side effect with excessive alarming under significant upset conditions.

Proactive stance. In proactive operations, we observe operators continuously scanning the process critical indicators to find signs that the equipment or control system is behaving abnormally. In some situations, they may even mildly perturb the system to verify that everything is well. This is true of operators at the control console as well as those in the field. If anything appears slightly askew, it triggers an investigation to better understand the systems behavior. Moreover, individuals will communicate with other team members or technical support personnel to help better understand. If there are early warning signs, individual team members are alerted to the possibility of future consequences.

Incident Orientation

The response of the plant organization to incidents has an impact on what the organization learns from the incident. We identified three kinds of reactions to incidents. Talk about how different cultures react to plant incidents. These specific kinds of reactions are manifestations of different cultures that teach individuals different things about how to operate the plant.

Finger pointing. The investigation of incidents identifies specific individuals as those accountable for its occurrence or escalation to a major event. Disciplinary actions are taken to teach people that this is unacceptable behavior. In extreme cases, individuals are fired for incompetence or negligence in their duties. There is a tendency for these organizations to report a small number of incidents. The incidents reported include significant observable events such as loss of life, major equipment damage, environmental release of contaminants, or significant loss of production.

In this type of environment, the operations team members cover for each other during the investigation when its possible. Individuals avoid reporting near-misses or incidents if there is no observable results that capture the attention of management or engineering. Often operations team members will establish the cause of the incident to be an equipment process failure. This practice protects individuals from blame and disciplinary actions. Individuals learn to tell others the “acceptable” explanations for incidents. The organization outwardly believes people are doing the best they can and the people are infrequently the source of abnormal plant situations. Hence there is a tendency for ineffective practices to perpetuate and solutions to focus on solving the wrong problems.

Fact finding. The investigation of incidents identifies the specific root causes and contributing causes for incidents. There is less emphasis on identifying the specific individuals responsible. Disciplinary actions are rare but likely if there is a history of repeated occurrences. There is usually a greater amount of explanatory detail in the incident report. There is greater tendency in a fact finding organization to report near-miss as well as minor incident events.

In this type of environment, the operations team members feel free to provide explanatory information without fear of retaliatory actions. Individuals provide information if requested but usually do not initiate an investigation. It is expected that management will decide if an investigation is warranted. A major inhibitor to reporting or initiating a report is fear of appearing stupid or incompetent to peers. In this culture, there is a willingness to admit that people are a frequent contributor to the cause and exacerbation of abnormal situations. Consequently, practices can be effectively improved following a incident. However, there is a tendency to only share the understanding locally within the groups directly involved. Moreover, the information in the reports are not used to enhance the operative knowledge across the organization or in the training of employees entering the organization following the event.

Operations improving. The investigation of incidents goes beyond event description and emphasizes operations improvement. Individuals take initiative and pride in contributing to the improvement of the operations. Peers reinforce sharing of incident information and discuss details collaboratively to improve their understanding of the process and appropriate operational activities.

In this culture, the incident report database is perceived as containing important information regarding the process behavior and effectiveness of the operations practices. There are many events reported annually. The analysis is used to focus site project efforts and operations team activities on factors most impacting effective operations.

Organization

The organization defines the relationships and roles of the collection of individuals in the plant work environment. (See Furnham, 1997 for detailed discussion on the individual in the organization.) In the plant work environment, organizational structure has tremendous impact on how effectively members of a operations team cooperate to achieve the goals of the company. Cooperation involves mutual coordination or assistance between members of a workgroup. In contrast, competition can develop when an individual of a workgroup gains at the expense of another. Competition often arises between operations teams as well. Cooperative and cohesive work groups produce benefits in terms of motivation, coordination, help, communications, and mentoring. It is imperative to effective, safe plant operations that people within and outside of the operations team work together to achieve common plant objectives. Moreover, when competition and clichés exist in workgroups information and knowledge is not shared because it provides individuals with an advantage over others. Hence, competition generally has negative impact on creating a continuous learning environment.

Workgroup Structure

The design of a workgroup can influence levels of cohesiveness and collaboration that promote higher levels of information sharing and mentoring. In particular, group size, member proximity and group roles are important to consider in understanding the nature of continuous learning in the work environment.

Group size. Operations workgroups vary in size from 3 to 20 depending on the size of the process area the group is structured around. When management organizes people in groups larger than twelve members, they find mutual interactions difficult and tend to subdivide into smaller groups. The consequence of group size beyond 7-9 people include inhibition in participation level, slower communications, and less satisfaction with performance. Most importantly, when tasks require a high level of interdependence between activities of team members, performance decreases with increase in size beyond the optimal size of 7-9 members.

Often group size is determined through a risk analysis that specifies the number of people needed to respond to emergency situations. However, plants should also consider the appropriate group size to adequately prepare people to respond to emergency conditions. This means provide adequate staffing to support the day-to-day learning necessary to ensure people have necessary competencies to execute emergency responses. A plant might have the right number of people but lack adequate competencies. Hence, the plant has taken on unacceptable risk to their operations.

Proximity. Group cohesiveness and collaboration is also influenced by proximity or physical closeness of group members. The more contact operations team members have with each other, the more cohesive the group can become. On the other hand, a cohesive group with significant past success can become complacent and show decrease in performance level. Cohesiveness alone is not sufficient to promote a continuous learning atmosphere.

We have observed significant impacts of proximity on the sharing of information between groups and within workgroups. If the main means of communication is the telephone or e-mail, communications tend to be less informative and goal oriented. Moreover, if a group shares a physical workspace for 12 hours a day, they have a better shared understanding of each other needs.

We discuss the proximity issue again in the discussion on workspace design. The current trend towards centralized control rooms has a negative impact on the cohesiveness and collaboration of operations teams, and at the same time, can strengthen the relationships between console operators sharing the control room space.

Group roles. Group roles are the implicit or explicit behavioral expectations for each individual as a member of the workgroup. Typically, individuals discover their group role as they learn to perform their job. A significant aspect of the individual role in the workplace is defined in terms of their specific job duties. The roles assigned to individuals in a workgroup influence levels of information sharing and mentoring.

Workgroup Interaction

Beyond workgroup structure, the organizational processes that govern how individuals interact in the workgroup delimit conditions that influence their level of cooperation. Specifically, decision making style, task interdependence and communication style determine key workgroup interactions that impact continuous learning.

Decision-making style. The extent of an individual's participation in the decisions that affect the operations practices of a operations team affects the degree to which individual group members feel a sense of ownership in the results. One way to characterize decision making styles is in terms of how members of the group affected by the decisions actually participate in the decision making process (See Figure 1). Most importantly with respect to development of operative knowledge, participation in defining training needs and activities impacts individual motivation to learn. In organizations where at least a delegated decision-making style is practiced, we have seen the most appropriate and effective training activities for members of operations teams.

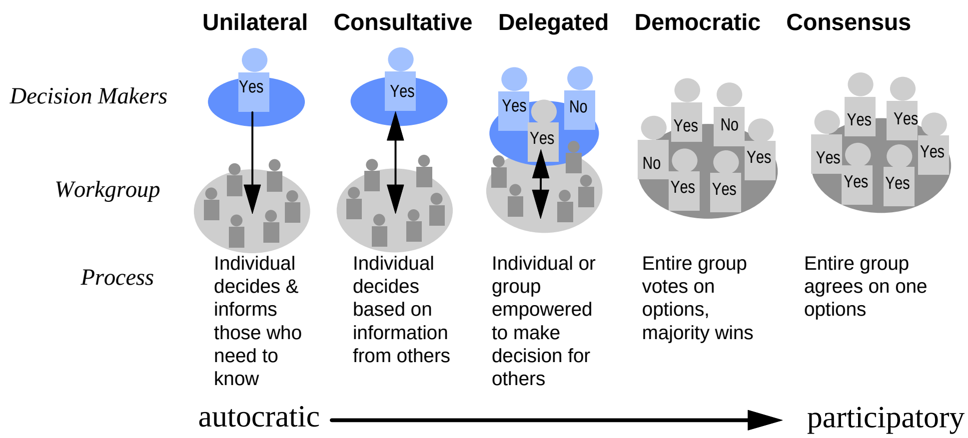

Figure 1. Decision Making Styles differ in Level of Group Participation

Task interdependence. Another important factor is task interdependence, if the members must work together to combine resources to achieve the workgroup goals, they will tend to be more cohesive. In addition, threat or competition can bring group members closer together. In normal operations, the operations team work in a process unit has a low level of task interdependence. Individuals have routine activities that they engage somewhat autonomously from those performed by other members of the group. However, under abnormal operation, the workgroup has a high level of task interdependence. Team members who have gone through a number of significant upsets together with positive experiences often become close knit, cohesive workgroups. Organizations could enhance level of cohesiveness through involvement in activities with interdependence in normal operations.

Communication styles. Communication styles characterize the way in which individuals express feelings and information to other members of the workgroup. The particular style of communication can encourage cooperation or inspire competition. Cooperation is fostered when descriptive rather than evaluative language is used. Moreover, when individuals take a problem orientation to assisting others, rather than a telling or controlling orientation, a spirit of cooperation is engendered. From the perspective of a recipient of a message, an attitude of willingness to learn or change invites others to offer assistance or instruction.

Workspace Design

Workspace design also impacts the nature of continuous learning resulting from day-to-day activities. However, the requirements for training are typically not considered as part of the initial design criteria of control rooms, workstations or the placement of computer based training systems. Training requirements are usually treated as an afterthought, if considered at all in the workspace design. When training is considered in the up-front design, it can become an intrinsic and unobtrusive part of the day-to-day operation of the plant (Cox and Easter, 1989).

In this section, we characterize how decisions to configure control rooms within the plant environment impacts continuous learning. This is the issue of distributed versus centralized control rooms. It is related to the topic of workgroup structure, in that it can present a physical barrier to learning that impacts workgroup communications and cohesiveness. In addition, we discuss how content and placement of information displays in the control room environment can influence learning. Finally, we briefly outline some issues related to use of computer-based training environments to enhance learning. Computer-based training can facilitate the implementation of a training strategy that entails unique capability appropriate to user needs and availability for instructional experiences.

Control center layout. The current trend in the process control industry to move towards centralized control rooms significantly affects the group dynamics of the operations teams. The impact of this decision often means that the member of the operations team that serves the role of console operator is physically located remotely from the rest of the team in a central control room. The principal impact on the console operator remote is a loss of situational awareness. The console operator, who cannot hear or see the process unit directly, is no longer involved directly in team conversations and issues that arise in the local unit control room. The main mechanism for contact is telecommunications. In addition, the communications problem is exacerbated by the fact that there are typically separate log books in the field and in the control room, which are not seen by all of the operations team. Because the console operator is remote from the unit, the field operators (particularly those who are not yet trained on the console) do not get an opportunity to learn the kinds of things the console operator does, and how important it is to understand the kinds of things that are going on in the unit. Thus, if and when field operators are promoted to the control console role, they must “start from scratch” in terms of learning how to operate the unit from the distributed control system. There is virtually no opportunity for day-to-day incidental learning that currently occurs in environments with distributed control rooms located in close proximity to the process unit.

As a general rule, the need for communications between the console operator and the other members of the operations team were observed to be the more frequent than communications between different unit console operators. As universally found on all plants we visited, console operators must communicate with field operators over a radio or a phone, which is very difficult, particularly in a noisy environment. Console operators and field operators did not always communicate as appropriate, either due to a lack of understanding of each other’s roles, not knowing how and when to communicate, or not realizing that a personal action would be relevant to the other person.

There is a general recognition of the need for improved understanding between operating groups where there is a direct supplier-consumer relation. This is one driver for creating centralized control rooms. In fact, we even observed some sites where there were plans to visit the control room of customer plants downstream of the site, as well as, host similar customer visits to their own control room. The intent of the exercise is to improve understanding of the nature of the processes in units that interact, the kinds of problems that can arise that will cause impact on each other and the different tactics for dealing with problems upstream and downstream to minimize propagation of effects. Hence, regardless of the approach taken, the design of the control center will impact the day-to-day learning activities of the operations team.

Information displays and resources. The design of information displays and devices in the console workstation includes the use of computer monitors, annunciator panels, traditional instruments and sound signals. Information should be arranged in these displays to support simultaneous viewing and interaction requirements anticipated for critical monitoring and control tasks. Appropriately designed displays illustrate to the operator directly how the plant behaves and is connected. A good design allows the operators to continually revise their knowledge during normal day-to-day activities.

The advent of graphic representations of the process in operator displays has had a significant impact on console operator's understanding of how the process equipment and control system behaves. At the same time, the loss of mimic boards has lead to a decrease in understanding of how a disturbance influences the system as a whole. People talk about the power of pattern recognition of information displays in helping operators understand the gestalt of the current situation. These patterns become implicit cues linked to appropriate responses in abnormal situations. These phenomena are manifestations of the impact of information displays on learning of operative knowledge.

A problem with the conventional selection and layout of information displays assumes that the book or declarative knowledge of plant processes that operators receive in training materials is well understood, completely assimilated by every operator, and the process data in the P&ID-based displays maps easily onto the book knowledge (Cox and Easter, 1989). A general strategy to enhance acquisition of operative knowledge through display design is to make sure the content and arrangement of information supports effective situation awareness of process status, functional models of the process and controls, and feedback of the results of control actions. For operations team situational awareness and learning, the use of large, dynamic, overview status displays to complement console operating displays in larger processes promotes visibility of process status to other console operators and/or operations team members. Topography and physical law should be observed in the arrangement of information elements. For example, process flow should consistently map onto information displays and devices arranged on screen or console from left to right flow patterns. The functional decomposition of the display schematics determines the navigation scheme and simultaneous viewing of key information when operators are monitoring or controlling the process. The functional design of the information displays can enhance operator effectiveness when it provides to appropriate task- and behavior-related compositions.

Computer-based training environments. Studies of human performance in the work place show that it is wrong to assume that, if a person is shown to possess a piece of knowledge in a circumstance, this knowledge should be available under all conditions in which it might be useful (Rizzo, Ferrante, & Bagnara, 1995). Possessing knowledge is not sufficient. Operative knowledge requires that relevant knowledge is available under the task conditions in which it is applicable.

When computer-based training (CBT) technologies include plant simulations, instructors can manipulate plant conditions in a safe environment and assist individuals in learning how to apply their book (declarative) knowledge to a particular plant condition. The advantage is that realistic situations can be simulated so that individuals acquire an in depth knowledge of the behavior of the process in response to their interactions. To the extent that the behavior is functional equivalent to the process that they will interact with, individuals can gain more confidence and competency in dealing with conditions that may occur infrequently or require a fast, accurate response.

A key to the success of simulation-based techniques is the juxtaposition of declarative knowledge with the experience of observing and interacting with the simulated plant behaviors. Effective instructional support assists individuals in understanding the critical relations between plant conditions, operational actions and process behaviors. Without adequate guidance, naive theories or superstitious understandings may evolve and the benefits of the technique will not be realized.

The benefits that CBT offers far outweigh the capital investment (when used effectively), even the lower cost packages used for small training modules can be very effective. A Texas petrochemical company recently replaced their old classroom training program with CBT modules. This allowed them to shutdown their training office. Moreover, they did not have to bring operators into work on scheduled days off for training. The cost savings consist of millions of dollars a year with a dramatic improvement in performance. From the continuous learning perspective, the CBT approach enables operators to train on the job in their every day work environment.

In general, CBT environments provide the operations team members with flexibility in accessing instructional information at their convenience, either to solve a current problem or to improve preparedness for future activities. It is important to establish a curriculum targeting specific competencies to ensure effective use of this learning resource.

A limitation of most computer-based techniques that impacts the transfer of learning include factors like organizational setting, human-human interaction and resource management. Future systems could provide more benefit if more of these kinds of influences are incorporated into the training exercises. Another alternative is to supplement these experience with the kinds of work practice described in the next session to provide a more comprehensive learning experience.

Continuous Learning Practices

Effective training to handle abnormal situations requires more than high fidelity simulation based training (Rogalski, 1995). The operational task is typically a collaborative activity involving other operational team members as well as people from other functional groups in the organization. Effective training should include dealing with conflicts about goals, negotiating resources and constraints, and handling the ways in which individual decisions can propagate effects to other people and processes in the plant setting. Hence, the training experiences should avoid oversimplifying interactions between tasks, communication constraints or complexity due to human limitations and possibilities for error.

Principles of Learning

Some training organizations take a more scientific view of designing training systems, they start from knowledge of how adults learn. Frank Bird and George Germain in their book on Practical Loss Control Leadership identify five basic principles of learning, they state these are obvious when read (Bird and Germain, 1992). However, they are often ignored, especially in adult learning situations. Consideration of five principles in designing a continuous learning environment will make employee training less frustrating and more productive for everyone concerned.

Principle of readiness. We learn best when we are ready to learn. You cannot teach someone something for which he or she does not have the necessary background or knowledge, maturity or experience. When people are ready and have sound reasons for learning, they profit from teaching and make progress. Readiness also means that the learner is emotionally ready, is motivated to learn. You help to create this readiness by letting learners know how important the training is, why they should take it, and the benefits it should bring them (such as growth, recognition, easier work, variety, challenge, safer work and increased potential). Helping to create the desire to learn helps people learn. (Canceling training because of budget cuts, bringing people in on overtime after three 12 hour night shifts, no involvement in the needs assessment is not the way to achieve this principle).

Principle of association. It is easier to learn something new if it is built upon something we already know. In training or teaching, it is best to proceed from the known to the new, to start with simple steps (based on what the learner already understands or can do) and gradually build up to the new and more difficult tasks or ideas. Make full use of comparison and contrast, of relationships and association of ideas.

Principle of involvement. For significant learning to occur, learners must be actively involved in the learning process. The more senses involved (hearing, seeing, tasting, smelling, feeling), the more effective the learning. The more fully the learners participate in the learning process, the more effectively they learn. The good instructor gets the learners to do the repeating, the practicing, the “learning by doing.” The good instructor uses learner involvement tools such as “hands on” training, question and answer, group discussion, audiovisual aids, case problems, role playing, simulations, quizzes and application exercises.

Principle of repetition. Repetition aids learning, retention and recall. Conversely, long disuse tends to cause learned responses to weaken and be forgotten. Application and practice are essential. Accuracy should be stressed before speed, to avoid learning a wrong habit that must later be "unlearned." The more often people use what they have learned, the better they can understand or perform it.

Principle of reinforcement. The more a response leads to satisfaction, the more likely it is to be learned and repeated. For best results in a teaching/learning situation, accentuate the positive (praise, reward, recognition, success). Also, breaking complex tasks down into simple steps allows the successful learning of one step to help motivate learning the next one. When learning is pleasant and beneficial, people more readily retain what they have learned, and are more likely to want to learn more. Successful learning stimulates more learning. The effective instructor facilitates learning climate. He or she uses feedback to satisfy learners' needs to know that they are doing things correctly and that they are making progress.

Training Program Components

A company should have a training program that includes a policy - a written, approved and published production operator training policy is critical to the development of a viable, sustained, effective, production operator training and certification program. The training policy lays down, in writing, the plant's mission, philosophy, and principles for operator training and certification. Often policy statements either don't exist or are vague, sometimes written by operators rather than management, and sometimes difficulties are experienced in getting needed approvals.

The training mission should clearly and precisely state the plant's and management's commitment to the training program and include statements similar to the following (Pankoff, 1997): Management shall ensure that all production operators are trained and certified to perform their jobs with maximum regard to safety, health, the environment, and regulatory requirements. The plant's training philosophy should include the intent, and commitment to operator training with statements such as the following: all production operators shall be trained and certified in the knowledge, attitudes, and skills required to perform their jobs to predetermined job standards.

As mentioned earlier, three important components of a good training program include: (1) needs assessment , (2) development and delivery, and (3) evaluation. To define an effective training strategy that involves designing the work environment for continuous learning, the plant should make sure these three components are part of the training program.

Needs assessment. The needs assessment phase should produce the set of competencies required for each individual job. A production operator is said to be qualified (declared competent to perform the job) when it has been verified that the employee can demonstrate the ability to perform a job to a predetermined level of competence in accordance with operating procedures. Hence, a job task analysis is required to define specific knowledge and skills necessary to achieve an acceptable level of competence for each job.

Development and delivery. Dedicated trainers (trained in training techniques and preferably drawn from operations) lead the operator training program. Experience is the primary criteria for selection as a trainer, other criteria includes knowledge, ability to express thoughts and ideas, demonstrated skill, desire to participate in training others, unit knowledge, interpersonal skills, oral and written communication skills, rapport with peers and supervisors, skilled in training techniques, aptitude testing, targeted selection process, willingness to be a trainer, and proven performance and availability.

Qualified operators have input into the training material. All operator shift teams should have some involvement in the development of the training program. One approach is to create an operator "training panel" consisting of representations from each operator team shift. In addition to facilitating the development of training materials, these individuals become team training facilitators in the deployment and evaluation of the training program. This operator training panel provides the vehicle for ensuring that the continuous learning atmosphere is established and reinforced on a daily basis on each operator shift team.

Evaluation. To know if training is effective, a program needs clear evaluation criteria and process for evaluating the impact on the performance of specific individuals . One approach to evaluation is to establish a certification process (Pankoff, 1997). Certification is a procedure that documents technical training and job performance. Certification of production operators documents the employee has acquired the knowledge, skills, and attitudes required to perform the job. This is verified by testing. The employee can perform the job with minimal supervision, while maintaining the required level of safety, quality, productivity, and regulatory compliance. This is verified by job observation and performance evaluation. While the certification process verifies the training program developed targeted competencies for individual employees, additional evaluation should determine the impact on job satisfaction, plant reliability , operational integrity, and operator responsiveness.

Best Practices

A best practice company learns to develop work force competency and enhance their operations performance as day to day events unfold. During an event they review progress towards a solution to a problem and note new experience which later can be shared with other team members, first as a learning exercise but also as preparation for any re-occurrence of the event during the rest of the shift. Well documented events can be shared with other operations teams, and if a simulator is available, they can reproduce the events and share the learning experience as the shift experienced the event. This is extremely important as each operations team experiences different events than another team on a different work shift.

In this section, we want to highlight some specific work practices that will help a company improve their performance through continuous learning in day-to-day activities in an appropriate socio-tecnical context. These practice descriptions are “best” practices we have observed in the petrochemical plant setting.

Handling incidents and near-misses. Incidents and near-misses provide a significant opportunity for teams to learn about their knowledge and skill, the behavior of the plant, and potential weakness in operations and maintenance practices. Handling near misses as well as incidents, gives the plant a more accurate understanding of their level of performance and the soundness of their operations practices. Effective incident handling practices include data collection where a form (paper or electronic) guides team members to document key information: description of the incident, probable causes and corrective action, along with responsibilities and a timetable for completion (Hettenhaus, 1992). To make the process more of a learning experience, the team should meet with all team members to perform analysis of incident, determine the recommended actions, and circulating a completed form as a lesson learned. After each serious event (actual or potential), there should be a formal review and training on the event to all of the operating teams to propagate the lessons learned.

Sharing experiences. Informally, operations people tend to share their memories for specific episodes to help solve current problems or to suggest potential solution to a team member (Samurçay, 1995). Unfortunately, the distributed episodic memories represent a vast corporate resource that remains unavailable to most plant personnel.

The idea here is to discuss possible ways for team members to highlight experiences regarding plant operations that can help existing team members as well as future team members. People often learn well from war stories, the idea here is to establish a plant practice to capture the war stories as the company’s lessons learned to pass important knowledge on to others. This can be outside of the near miss or incident reporting system. For example, these cases could be stories to reinforce good practices that have lead to successful interventions.

Practicing team responses. The concept of expertise should affect our conceptions of operators’ daily activities. Expertise in supervising automated systems requires a conceptual understanding of the uncertainty inherent in the process (Norros, 1995). If work is conceived as mere routine, being prepared for problems and learning are hindered. To improve and maintain operational expertise, one needs to reduce the gap between crisis and routine activity. Specifically, the routine activity must include continuous preparedness of the operations team to respond to abnormal and emergency plant conditions.

We have seen many striking examples of the value of operations team members having an implicit understanding of each other’s activities. This is a critical component of operational knowledge, particularly, during abnormal situation intervention where there is a high level of task interdependence. The console operator needs to have enough understanding of the field operator’s activities that he can predict how long certain activities will take and whether the individual will need assistance. Meanwhile, the field operator needs to know what the console operator is trying to accomplish, so she can be aware of the kind of information that may be useful to help solve current problems.

Team response practice activities should anticipate possible problem situations, analyze previous problem situations, identify critical knowledge and appropriate procedural responses. Each member of the operating team should have clearly documented roles and responsibilities during an abnormal or emergency situation. During relatively quiet times, the operating team can review situations that might arise given current status of the plant. The team should review appropriate procedures to retain familiarity with the necessary response steps. This approach reveals weaknesses in each team members knowledge of their own responsibilities as well as those of other team members. Moreover, the review of the procedure may identify potential limitations or out datedness of the documented response. The development of a strategic practice response plan will help each operations team establish continuous practice for critical situations for their process area.

Conclusion

Explicit or implicitly, every company has a training policy that determines the nature of the continuous learning that occurs within the work environment. This day to day learning accounts for the majority of what people know about doing their jobs. It is time for industry to take advantage of a tremendous opportunity to create an effective training strategy.

Creation of a work environment to effectively structure and motivate the continuous learning of the work force is an essential part of meeting today's training demands in the process operations work environment. The current training approach cannot and does not adequately support the training needs. To improve the effectiveness of learning that takes place within the plant during on-the-job activities, plant developers and managers should design the work environment as an effective learning environment.

The dimensions of continuous learning represent specific aspects of the work environment that influence day-to-day activities that can have either a positive or negative influence on operational performance. Specifically, these aspects of the work environment include culture, organization and work space design. Understanding these dimensions of learning is a critical first step to rethinking the plant training strategy. The next step is to assess the nature of a specific continuous learning environment to identify areas for improvement that address a company's specific problems or competency deficiencies.

One key to success will be to build on the existing culture and organization. Where significant cultural and organizational changes are necessary, specific individuals should be established as change agents (Hettenhaus, 1992). Both internal and external change agents may be required to effectively transform the work environment. An internal change agent is an individual within the company that can ensure that communications are occurring and that an understanding of the purpose for the change and the tasks and activities related to the change process are properly interpreted and executed. External change agents are individuals who specialize in the specific areas of change that might be needed and can facilitate the design and implementation of effective practices.

We believe a new paradigm in training is needed to make a significant improvement in competencies of the work force in the process control operations work environment. Ironically, this “new paradigm” is likely to prove successful precisely because it captures the best aspects of an existing culture, organization and practice and builds upon them.

The paradigm shift will also help deliver the anticipated benefits that the ASM Consortium believe are achievable namely a 90% reduction in preventable incidents. The consortium have identified that the chemical process industry only have two major initiating events that cause all abnormal situations. These are equipment reliability which is well understood, and recently has been receiving new focus as we strive to achieve our goals. The second major initiating event is people reliability issues. These manifest themselves in many different areas from design, operations and maintenance activities. They are preventable, just like equipment health management there is a requirement for measurement, analysis, and corrective action. Training is a key area that requires change in order to improve human reliability and the probability of failures or abnormal situations.

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