Tackle Abnormal Situation Management® With Better Training

A new paradigm is needed to increase job satisfaction, plant reliability, and profits. Keys include coupling of training and job activities, and designing the work atmosphere to be a continuous learning environment.

Peter Builemer,
Honeywell Technology Center
Ian Nimmo,
Honeywell Industrial Automation & Control

In the industrial workplace, few people begin a job fully trained. Even when people have prior experience, they will still need to learn the many nuances of the new work environment that impact on one's ability to perform effectively. Furthermore, with the current high rate of change in organizations 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 experience, and 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 (1).

The purpose of training is to develop task-appropriate competencies as specific knowledge and skills. Most importantly, when people are interacting with large complex systems such as those used for control in the chemical process industries (CPI), the system's structure and behavior change continuously for a variety of reasons. Consequently, the competencies of the work force must keep abreast 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 just the technical aspects of operating and maintaining plant equipment, machinery, and controls. (For a full list of the range of competencies, see Ref. 2.)

Aspects of a good training program

A good training program differentiates the way in which people work, but should provide a standardization of approach. Good training can and should be (3):

• A focus for aligning the work force with the company strategy;
• A means to ensure that work force skill levels are up to national or industry standards;
• A powerful individual motivator;
• A good catalyst for change; and

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An arena for providing a link between the individual and company values.

An assessment we made of current training practices concludes that many of today's industrial training programs fall short of these qualities (1). Quite by accident, the most influential training is on-the-job training; even as it tends to be sporadic, informal, and unmeasured. The interactions within the everyday work environment have a stronger impact on an operations team's performance than does any training program. The work environment is the primary learning environment, but, unfortunately, is not perceived as such.

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 will present key dimensions for continuous learning in terms of culture, organization, and workspace design. Explicit design of the work environment along these dimensions will lead to greater job satisfaction, increased plant reliability, better operational integrity, and, most importantly, improved profits.

Assessing 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 (4). Regardless of a person's knowledge and competency in a particular area, performance depends on motivational considerations like cost and rewards, self-esteem, self-confidence, and pressure to conform.

Use of traditional methods

As we seek to enhance or replace these traditional methods, we need to understand their strengths and weaknesses:

- **Heritage** - Industrial manufacturing has a rich heritage. In the last 10 years, training of production operators has evolved due to changing environmental and regulatory 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 awareness. Training has resulted in more-planned, structured, and documented performance-based solutions.

- **Citations** - Some of today's training challenges are highlighted by U.S. Occupational Safety and Health Administration (OSHA) and U.S. Environmental Protection Agency (EPA) citations which point out weaknesses in existing practices. Training violations comprise about 10% of total plant safety management citations. Inadequate initial training is the number one offense. Measuring the adequacy of training has been identified as a tough issue to solve.

- **Curriculum** - An organization must have a structured curriculum such that new and seasoned employees can measure their progress and achievements. Most companies are challenged to do this since they no longer have dedicated trainers concentrating on this topic. Before the development of a curriculum, a company needs to complete a needs assessment that includes competency evaluation. This task can be done with the aid of training consultants. Good consultants are familiar with industrial training initiatives such as the new recruiting philosophy being adopted whereby a company will only employ operators who have completed an industrial foundation training diploma or a 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 its needs are being addressed in the foundation training.

- **Benchmarking** - More than 58% of refineries, 57% of petrochemical plants, and 36% of chemical companies do some form of benchmarking of their operator training practices.

Common practices

Surveys have been done to identify the most successful operating training practices as noted by the end users (2). These surveys illustrate slight differences among various industrial groups within the CPI. Some common methods that are successful across all groups include:

- On-the-job training using procedures and training manuals with introductory classes;
Balancing the methods

Successful training practices effectively balance the various training methods (2). In petroleum refineries, initial training is typically evenly balanced between the classroom and the field. Specific job training uses more field training (75%) relative to classroom instruction (25%). In general, companies reviewing training practices of other organizations need to make sure that 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 its 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; and
- Staffing.

Use of training program components

We conducted a study of 12 refineries and determined three important components of an effective training program (1):

Training needs assessment This 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. Yet, assessment of performance enables an organization to understand areas for improving competency levels. Consequently, these organizations had a limited ability to design training programs that addressed specific individual or team competency development needs.

Training development and delivery - Such practices were a ubiquitous concern among all plant personnel. Apprenticeship training emphasized informal hands-on and on-the-job training. We found significant organizational obstacles that affect 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 Findings here were similar to those of needs assessment. We did not find formal or systematic methods being used. The limited training evaluation focused on short-term effects of hands-on training. In general, training specialists did not know the impact of their training programs.

Dimensions of continuous learning

Examining continuous learning reveals how specific aspects of the work environment influence day-to-day activities that can have either a positive or negative influence on performance. "Learning" is defined as the acquisition of knowledge and skills needed to effectively operate the plant as a collaborative work force. We use the term "continuous" to emphasize that people are constantly learning about operational knowledge and acquiring skills while they perform their day-today activities. Understanding these dimensions of learning is a crucial first step to rethinking the operator training strategy.

Culture
Organizational culture consists of the values and beliefs that either explicitly or implicitly determine acceptable behaviors (5). 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. For example, cultures exist in a refinery, with subcultures within a specific process unit. The operations team's cultures are the most influential in teaching new employees the acceptable 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.

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.

There are a number of ways to develop a culture. From the perspective of establishing a continuous learning organization, one needs to identify the important norms and desired behaviors. As examples, we will present three types of behaviors that determine the kind of continuous learning culture that exists in the operations work environment.

Policy compliance

Compliance to published guidelines and policies fosters uniformity of operations practices. 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's needs or match individual preferences. Types of policy compliance include:

"Do as I do" - Some work groups accept behaviors that deviate from published guidelines and policies. We characterize this as, "Do as I do, not as it [the policy] says." It is difficult to eliminate this culture through management decrees. Experienced individuals mentor others to do it their way because it is better or more convenient.

"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 these groups to achieve compliance. Also, these groups tend 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. We use the term "posture" to characterize the operator's attitude in performing these duties. While operators assume different attitudes, the operations team culture tends to promote a dominant posture which influences the general level of understanding and competency in preventing and responding to process disturbances. We identified two basic operating postures:

Reactive stance - In reactive operations, operators wait for something to happen. They perform routine activities and wait for the alarm system to alert them about an abnormal condition and then they go into the proverbial "fire fighting" mode to stabilize the process. Once done, they investigate the root cause of the disturbance. 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 prealarms 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 - Here, operators continuously scan the process's critical indicators to find signs of abnormal operation. Sometimes, 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 system's behavior. Moreover, individuals communicate with other team members or technical support personnel to help their understanding. If there are early warning signs, team members are alerted to the possibility of future consequences.

**Incident orientation**

The response to incidents has an impact on what the organization learns. We identified three kinds of reactions to incidents:

*Finger pointing* - Here, disciplinary actions are taken to teach people that this is unacceptable behavior. In extreme cases, individuals are fired. Not surprisingly, there is a tendency to minimize the number of incidents reported. Those reported include significant observable events such as loss of life, major equipment damage, environmental release of contaminants, and major production loss.

Whenever possible, operations team members cover for each other during an investigation. Individuals avoid reporting near-misses or incidents with no observable results. Often, team members will establish the cause of the incident to be an equipment process failure just to protect an individual. Individuals learn to tell others the "acceptable" explanations for incidents. The organization outwardly believes that people are doing the best they can and that people are infrequently the source of abnormal plant situations. This perpetuates ineffective practices and focuses on solving the wrong problems.

*Fact finding* - This investigation identifies the specific root causes and contributing factors for incidents, with less emphasis on identifying specific individuals. Disciplinary actions are rare. There is usually a greater amount of explanatory detail in the incident report. The tendency is to report near-misses, as well as minor incidents.

Operations team members feel free to explain 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 share the understanding only locally within the groups directly involved. Moreover, the reported information is not used to enhance the operative knowledge across the organization or in the training of employees entering the organization.

*Operations improving* - In this, individuals take initiative and pride in contributing to the improvement of 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 focuses site project efforts and operations team activities on factors most impacting on effective operations.

**Organization**

The organization defines the relationships and roles of the collection of individuals in the plant, impacting on how effectively members of an operations team cooperate to achieve the goals of the company. (For a detailed discussion of the individual in the organization, see Ref. 3.)

However, in contrast to cooperation, competition can develop when an individual gains at the expense of another. Competition often arises between operations teams as well. When competition and clichés exist in workgroups,
information and knowledge are not shared. Hence, competition generally has negative impact on creating a continuous learning environment.

**Workgroup structure**

Workgroup design influences cohesiveness and collaboration, which promote higher levels of information sharing and mentoring. Key factors here are:

*Group size* - In groups larger than 12 members, workers find interactions difficult and subdivide into smaller groups. The consequences of group size beyond 7-9 persons include inhibition in participation level, slower communications, and less satisfaction with performance. Most importantly, when tasks require a high level of interdependence, performance decreases with an increase beyond the optimal size of 7-9 members.

Often, group size is determined through a risk analysis. However, plants should also consider the size needed to adequately prepare people to respond to emergency conditions. This means providing adequate staffing to support the day-to-day learning necessary to ensure that people have the 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.

*Proximity* - 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 decrease its performance level. Cohesiveness alone is not sufficient to promote a continuous learning atmosphere.

We have observed significant benefits from 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, members have a better shared understanding of each other's needs.

*Group roles* - Group roles are the implicit or explicit behavioral expectations for each individual. Typically, individuals discover their role as they learn to perform their job. A significant aspect of the individual role is defined by 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 set out conditions that influence their level of cooperation. Specifically, decision-making style, task interdependence, and communication style determine key workgroup interactions that impact on continuous learning.

*Decision-making style* - The extent of an individual's participation in the decisions that affect the operations practices influences that member's sense of ownership. One way to characterize decision-making styles is how group members affected by the decisions actually participate in the decision-making process (Figure 1). Most importantly, participation in defining training needs and activities impacts on individual motivation to learn operative knowledge. We have seen the most appropriate and effective training activities where decisions are not simply delegated.

*Task interdependence* - If the members must work together to achieve the workgroup goals, they tend to be more cohesive. In addition, threats or competition can bring group members closer together. In normal operations, a process-unit operations team has a low task interdependence. Individuals have routine activities that they engage in somewhat autonomously. 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 the level of cohesiveness through involvement in activities with interdependence in normal operations.

*Communication styles* - A 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.

**Workspace design**

Workspace design also impacts on the nature of continuous learning resulting from day-to-day activities. However, training requirements are typically not considered as part of the design criteria of control rooms, workstations, or the placement of computer-based training systems. Such requirements are usually treated as an afterthought, if considered at all. When training is considered in the upfront design, it can become an intrinsic and unobtrusive part of the day-to-day operation of the plant (6). Examples of poor design include locating training rooms and simulators away from the control room. This usually limits the simulators usability to "off-shift training."

We have seen two independent requirements for operator training, one "off-line" and the other "on-line." The off-line training is currently done during over-time hours and the shift team comes into work on scheduled days off specifically for training. The environment for this type of training needs to be away from the busy control room, but close to the control room resources such as documents, procedures, and on-line systems. It is often just as important that the operator learns what support materials to use during an abnormal situation (as well as how to use them) as it is learning the control system. Many failures and incidents have occurred because of weaknesses, unfamiliarity, and lack of knowledge of management systems.

The second type of training is "online" or mentoring where an apprentice learns from existing operators, first by observation, then by performing simple, straight-forward tasks, and finally by taking full control and being observed by the skilled operator or supervisor.

This type of training needs to be in the control room environment because that is where the mentor and equipment are. Unfortunately, the skilled operator cannot currently prepare the student for a lot of the potential

*Figure 1. Decision-making styles differ in their level of group participation.*
situations because they are infrequent and may not happen for hours, days, weeks, and, in some plants, years. We have witnessed some plants which have junior shift teams that have never experienced a plant shutdown and, more importantly, a plant startup.

So, provision of a training facility within the control room environment can solve both of these issues. Having a closed-off section for off-line training, yet providing access to the real documentation and management systems in the control room, and using a configurable panel connected to the simulator could allow shift teams access to refresher training in the control room and ensure that the facility trains new operators for different and challenging scenarios. The only challenge the designer has is to ensure that the operator using the dedicated panel never confuses the training for the real system and vice versa. This can be done by using a dedicated engineers' console which is only used for operations during startup and development.

There is the basic issue of distributed vs. centralized control rooms:

*Control center layout* - The CPI are moving toward centralized control rooms, and this significantly affects the group dynamics of operations teams. Centralization often means that the console operator in a control room is remote from the rest of the team. The console operator is not involved directly in team conversations and issues that arise in the local unit control room. Telecommunications is the main mechanism for contact.

In addition, the communications problem is exacerbated because there typically are separate log books in the field and in the control room that 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 what the console operator does, and how important it is to understand what is going on in the unit. Thus, if and when field operators are promoted to the control console role, they must start from scratch in learning the distributed control system. There is virtually no opportunity for day-to-day incidental learning as there is with distributed control rooms in close proximity to the process unit.

Generally, we found communications between the console operator and the operations team were 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 difficult, particularly in a noisy environment. Console operators and field operators did not always communicate appropriately, due to not understanding each other's roles, not knowing how and when to communicate, or not realizing that an action would be relevant to the other person.

Best-in-class plants rotate operators ensuring that every job is filled by a competent person. It takes a long time to achieve this. Most companies estimate 6-10 years with operators starting their lives in field positions. When competent, they work their way into the control room to the more complex and challenging console operator roles.

There is a need for improved understanding between operating groups where there is a direct supplier-consumer relationship. 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 to host similar visits to their own control room. The intent was improving understanding of the processes via units that interact, the kinds of problems that can impact on each other, and the 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 would impact the day-to-day learning activities of the operations team.

A common issue observed in several refineries is the impact of feed composition changes on the fluid catalytic cracking units (FCCUs). Feed composition often changes because of modifications in one of potentially a half-dozen sources of feed stock. In many cases, these modifications are part of an inventory management strategy. If operators have a better understanding of how feed changes has impact on the FCCU process, they are more likely to inform another operator in advance about planned changes. However, in many instances, the upstream operators never find out that the feed change has caused a disturbance in the FCCU unless the FCCU operator contacts them.
**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 audible sound signals. Displayed information should support simultaneous viewing and interaction for critical monitoring and control tasks. Appropriately designed displays illustrate directly how the plant behaves and is connected. A good design allows operators to continually revise their knowledge during normal day-to-day activities.

This is one significant best practice that was lost when control rooms evolved from the large mimic panel to a single workstation. Some companies are migrating back to this practice by providing large overview screen displays strategically positioned in the control room.

Graphical representations of the process have significantly impacted on the console operator's understanding of how the process equipment and control system behave. At the same time, the loss of mimic boards has decreased 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 to understand the *gestalt* of the current situation. These patterns become implicit cues linked to appropriate responses in abnormal situations.

A recent incident in the U.K. involved an unscheduled plant shutdown and startup. During startup the operator's attention was focused on a small section of the plant involving filling vessels with liquid and on managing pressures, temperatures, and flows. A stuck valve (closed) on the debutanizer outlet during liquid filling indicated "open" and was not identified or diagnosed due to lack of overview. There was no management of liquid flows and mass balances. A distracting plethora of low-priority instrument alarms flooded the screens. Many of these alarms were unnecessary and were registering with increasing frequency, so, operators were unable to appreciate what was actually happening. This incident led to a large explosion and fire that resulted in damage costing over $75 million.

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 and completely assimilated, and that the process data in the P&ID-based displays map easily onto that book knowledge (6). A general strategy to enhance acquisition of operative knowledge through display design is to ensure that the content and arrangement of information supports effective situation awareness of process status, functional models of the process and controls, and feedback 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 or operations team members. Topography and physical laws 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 breakdown 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 workplace performance show that it is wrong to assume that, if a person possesses a piece of knowledge in a circumstance, this knowledge should be available under all conditions in which it might be useful (7). Possessing knowledge is not sufficient. Operative knowledge requires that relevant knowledge is available under the task conditions in which it is applicable.

When 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 response of the process to their interactions. if the behavior is the functionally equivalent to the process that they will interact with, then 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 observing and interacting with the simulated plant behaviors. Effective instructional support assists individuals in understanding the critical relations among 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 (when used effectively) far outweigh its capital investment; even the lower-cost packages used for small training modules can be very effective. A Texas petrochemical company recently replaced its old classroom training program with CBT modules. This allowed the firm to shut down its training office. Moreover, it did not have to bring operators into work on scheduled days off for training. The 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 everyday work environment.

In general, CBT environments provide team members with flexibility in accessing instructional information at their convenience, either to solve a current problem or to improve preparedness for future ones. A curriculum targeting specific competencies must be established to ensure effective use of this learning resource.

A limitation of most computer-based techniques that impacts on the transfer of learning includes factors such as organizational setting, human-human interaction, and resource management. Future systems could provide more benefit if more of these kinds of influences are considered during training. Another alternative is to supplement CBT 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 (8). The operations task is typically a collaborative activity involving other operational team members, as well as people from other functional groups. 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. Hence, training should avoid oversimplifying interactions among tasks, communication constraints, or complexity due to human limitations and possibilities for error.

We have visited several plants where relationships between individual operators and engineers have completely broken down. Engineers often overwhelm stressed panel operators by attempting to deliver a chemistry lesson during a disturbance or wanting to do an in-depth discussion and investigation. The operator wants to contain and isolate the problem, and return the process to its normal operating mode; as far as the operator is concerned, an in-depth investigation can be done later.

The operator is often interacting with the process by taking control loops off automatic control and manually manipulating valves to achieve stability. The operator always has in the back of his or her mind that the decision may have to be made to shut down the plant, which will also mean a startup. This decision process involves the assessing of operating goals including safety, environmental impact, quality, productivity, and cost.

The engineer is often not aware of the extra stress that is introduced by trying to take control of only one element of a problem that the operator is managing. It is often observed that it is only during these situations that the operator and engineer interact. This is not an ideal environment for them to learn to work together and to understand each other's unique skills and talents, and to have confidence and trust in each other.

The operator has the responsibility for what actions are taken. These often include clearing the control room of unnecessary personnel, sometimes including the engineer. This can be seen as "throwing the baby out with the bath water" and is not recommended.

The best way to develop good working relationships between these groups of individuals is to work together on problem solving tasks that have no time constraints or stresses. The simulator is the ideal tool and environment to achieve this task. The operator and engineer can work together using defined scenarios and, during the exercises, they will develop confidence in each other's skills, as well as understanding of each other's strengths and weaknesses. Also, the operator can receive a better understanding of the process and its chemistry from the
engineer, and the engineer will get real life experience from the operator on how the process and control system actually work together.

At a recent site visit, we witnessed the impact of this working relationship when an operator who was shy of completing a task, which would have impacted on business, was persuaded by a respected engineer that the temperature in a reactor could not go above a certain point based on physics and chemistry; beliefs had been based on false information and poor communication. The operator was confident that the engineer was correct, and put trust in his recommendations and carried out the task, improving operations.

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 (9). The authors state that these are obvious when read, however, they are often ignored, especially in adult learning situations. Consideration of the following principles in designing a continuous learning environment will make employee training less frustrating and more productive:

1. 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, knowledge, maturity, or experience. Readiness also means that the learner is emotionally ready, and 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 to learn. (Canceling training because of budget cuts, bringing people in on overtime after three 12-hour night shifts, and not involving operators in the needs assessment is not the way to achieve this principle.)

2. 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, and of relationships and association of ideas.

3. Principle of involvement - For significant learning to occur, learners must be actively involved in the process. The more senses involved, 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, and 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.

4. Principle of repetition - Repetition aids learning, retention, and recall. Conversely, long disuse tends to cause learned responses to weaken if not 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.

5. 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. 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 the learning climate by using feedback to satisfy learners' needs to know that they are doing things correctly and 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, and effective 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 are written by operators rather than management, and, occasionally, difficulties are experienced in getting needed approvals.

The training mission should clearly and precisely state the plant and management's commitment to the training program and include statements similar to the following (2):

"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 ensure that 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 he or she demonstrates the ability to perform that 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 criterion for selection as a trainer; other criteria include:

- **Knowledge** - know the subject, the plant, unit knowledge, equipment, and process;
- **Skills** - these are interpersonal, written communications, and training techniques. Included are the ability to express thoughts and ideas, interpersonal, oral, and written communications skills, rapport with peers and supervisors, skill in training techniques, aptitude testing, and targeted selection process; and
- **Motivation** - desire to participate in training others, not just making a sideways move, as either a job downgrade or a retirement project.

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

**Evaluation** - To know if training is effective, a program needs clear evaluation criteria and a process for evaluating its impact on the performance of individuals. One approach is establishing a certification process (2). Certification documents technical training and job performance. Certification of production operators documents that the employee has acquired the knowledge, skills, and attitudes required to perform the job.

This is verified by testing. The employee should perform the job with minimal supervision, while maintaining the required level of safety, quality, productivity, and regulatory compliance. This is confirmed by job observation and performance evaluation. While certification verifies that the training program has developed targeted competencies for individual employees, additional evaluation should determine the impact on job satisfaction, plant reliability, operational integrity, and operator responsiveness.
This can be achieved by peer evaluations twice a year ("360-degree reviews") and job satisfaction surveys. Shift teams should be established that have competent, experienced (more than 5 years) veteran operators in each of the positions. When a vacancy occurs, lots of people want it. This is in contrast to the companies that can not keep personnel and have plant reliability problems. Unreliability takes two forms; people and equipment. Equipment reliability is easy to track through incident reports and maintenance records. Human reliability issues are harder to track, especially if motivation is low. However, by implementing abnormal situation management culture changes, such reliability can be tracked and eliminated.

**Best practices**

A best-practice company develops workforce competency and enhances its operations performance as day-to-day events unfold. During an event, it reviews progress towards a problem's solution and notes new experiences which later can be shared with other team members, first as a learning exercise, then later on as preparation for any reoccurrence of the event. Well documented events can be shared with other operations teams; if a simulator is available, it can reproduce the events and share the learning experience. This is important as each operations team experiences events different from those on another shift.

Now, we will highlight some specific work practices that will help a company to improve its performance through continuous learning in day-to-day activities in an appropriate sociotechnical context. These practices 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 weaknesses in operations and maintenance practices. Handling near misses, as well as incidents, gives the plant a more-accurate understanding of its level of performance and the soundness of its operations practices. Once this practice has been adopted and supported, the plant should raise its standards and improve people's behavior by measuring the daily errors and corrections that are initiating events for problems. These problems sometimes escalate to either a near miss or an incident. Such problems most often are corrected before anything noticeable or significant happens, but often result in quality or minor production issues. Effective incident-handling practices include data collection in which 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 (10). To make the process more of a learning experience, all team members should meet to analyze the incident, determine the recommended actions, and circulate 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 for all of the operating teams to propagate the lessons learned. A best practice is for all plant personnel to work through learning events once a year. Trevor Kletz has written a unique book that could be used as a good starting point (11).

*Sharing experiences* - Informally, operations people tend to share their memories for specific episodes to help solve current problems or suggest a potential solution to a team member (12). 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 operators to highlight experiences that can help existing, as well as, future team members. People often learn well from war stories; establishing a plant practice to capture the war stories as the company's "lessons learned" can help 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* - Expertise in supervising automated systems requires a conceptual understanding of the uncertainty inherent in the process (13). If work is conceived as being mere routine, keeping prepared for problems and learning is hindered. To improve and maintain operational expertise, one needs to reduce the gap between crisis response and routine activity. Specifically, routine activity must include continuous preparedness 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. These include understanding time constants and how long it will take to accomplish a
task; and panel operators understanding the location of equipment in the plant and preparing a strategy for a field operator to achieve manual manipulation without unnecessary trips up and down stages of the process. Sometimes, the panel operator may know the tasks that need more than one person to be accomplished, and will either automatically coordinate other resources, or, in some plants, actually go out to the plant to lend a hand.

We have also seen operators perform their daily tasks differently based on atmospheric conditions. Examples are extreme cold, lightning, and thunderstorms when radios are not effective. 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 so that he or she 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 he or 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 problems, analyze previous problem situations, and identify critical knowledge and appropriate procedural responses. Each team member 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 the current status of the plant. The team should review appropriate procedures to become familiar with the necessary response steps. This approach will reveal weaknesses in each team member's knowledge of his or her own responsibilities, as well as those of other team members. Moreover, the review of the procedure may identify potential limitations or out-dateness of the documented response. The development of a strategic practice response plan will help each operations team to establish a continuous practice for critical situations for their process area.

**Explicitly or implicitly, every company has a training policy that determines the nature of the continuous learning that occurs within the work environment.**

A good example of this was when a plant compressor's pretrip alarm warning was activated. The operations team took corrective actions. Operators who controlled a different part of the plant responded to the situation by tracking alarms, monitoring stable parts of the process, and acting as coordinators for the team that was trying to resolve the situation. At the conclusion of the situation, the whole team met to discuss the problem, the actions taken, strategies used, and review the actions and who would implement them should the situation worsen or not be resolved as thought. This review can include planning to swap positions based on skills and knowledge. The team effectively reviewed what-if scenarios and the operating procedures that may need to be implemented and discussed any deviations based on plant conditions.

**To sum up**

Explicitly 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 in 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 essential in meeting today's training demands in process operations. The current training approach cannot and does not adequately support 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 climate 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 (10). Both internal and external change agents may be required to effectively transform the work environment. An internal change agent is someone in the company who 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 are properly interpreted and executed. External change agents specialize in the specific areas of change that might be needed, and can facilitate the design and implementation of effective practices.

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

The paradigm shift will also help to deliver the anticipated benefits that the Abnormal Situation Management Consortium (14) believes are achievable, namely a 90% reduction in preventable incidents. The consortium has identified that the CPI only have two major initiating events that cause all abnormal situations. The first is equipment reliability, which is well understood and recently has been receiving new focus as we strive to achieve our goals. The second is human reliability issues. These events manifest themselves in many different areas such as design, operations, and maintenance, and are preventable. Just as in equipment health management, there is a requirement for measurement, analysis, and corrective action. Training is a key area that requires change to improve human reliability and lower the probability of failures or abnormal situations.