White Paper:

PlantMentor®
Advanced On-line Training and Qualification for Technical Personnel

by

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Experience is a Very Painful Way to Learn

Time and time again, petroleum refiners, petrochemical plants, and chemical plants have to relearn the lessons of the past through unit upsets, incidents, unplanned outages, and low production rates. Collectively, they have spent billions of dollars implementing advanced process control systems designed to improve operational performance, improve safe operations, and reduce risk by reducing or eliminating the often devastating effects of these events. With each new technology implemented, the operators – holding the "keys" to the unit, get further away from the "steering wheel."

Historically, process units were run from control rooms with controls and instrument repeaters installed over a process map that was painted on the control room wall. Controls and instrument repeaters appeared in the same positions relative to each other and to their actual positions in the field and operators could:

- See most, if not all, of the unit in one view.
- Assess the impact of each control move or parameter change as it worked its way through the unit over time.
- Gather around the process map in groups to brainstorm control moves or troubleshoot off-specification situations.
- Readily train new personnel using the process map to develop a common mental model of the unit and its operation. New personnel could easily relate what they were seeing in the control room to the actual unit.

The chief drawback to this kind of unit operation is that operators tended to run their units in the "heart of the envelope" and away from the operational boundaries. Operating the units this way was safer, but it also kept the unit from achieving its operational potential.

Distributed control systems (DCS) brought a new and unparalleled level of precision enabling personnel to control process parameters on a far more granular level. The promise of DCS systems was automated process control of the unit running much closer to its design, conducted to a far finer degree than humanly possible, with the control system recognizing and responding to adverse situations faster and more reliably than human operators could. With DCS, personnel can view, examine, control, and record unit parameters and can quickly determine the status of simple systems from a single screen, but it is impossible to view the entire unit at once. The deep understanding operations personnel once acquired by gathering in the control room around the process map and sharing knowledge and perspective was eventually lost over time – a process called "knowledge leakage."

Operations can now run process units longer and harder than ever before. As such, the impact of "knowledge leakage" has manifested itself since the early 1990's through increasing numbers of unit upsets, incidents, and lost production. Lost production may result in internal repercussions such as lost revenue opportunities or increased costs, but upsets, incidents, and accidents often result in unplanned shutdowns, environmental releases, damaged equipment, adverse media attention, or worse ... Operators, relying only on experience, tend to interpret their limited view of the unit incorrectly and make poor troubleshooting or operational decisions when the control system encounters scenarios that are not programmed or when equipment or instruments fail. Sometimes they can relate parameter symptoms they are seeing on the DCS screen to previously experiences or scenarios, but sometimes they cannot. Additionally, scenarios with similar symptoms often have radically different root causes.

The question Management should ask is:

> How can I help my operators regain the depth of knowledge they once had and improve my safe operation statistics through better troubleshooting?

The answer is Deploy PlantMentor.

PlantMentor Philosophy and Design

Since 1988, GP Strategies has accumulated significant experience in process unit operations. During this time, GP Strategies interacted extensively with all levels of operations and created and validated the operational performance competence model depicted in Figure 1.

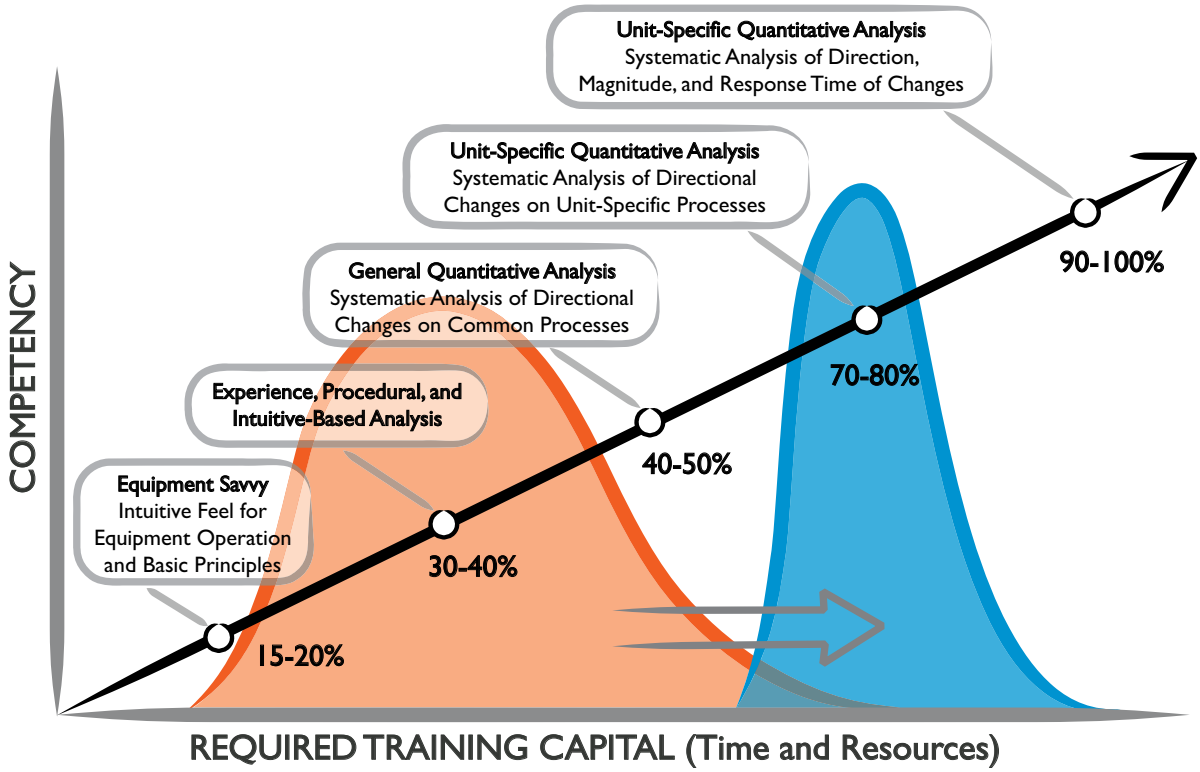

Figure 1: Operational Performance Competence Model

The model illustrates a five-level continuum of operational performance competence. At the left end, operators typically have only a basic understanding of unit operations that focuses on equipment operation. Over time, they gain unit experience and progress to a stage where they become comfortable using a combination of physical tools (procedures, P&IDs, PFDs, etc.), their experience, and intuition to control unit operations. Many operators stagnate at this level of competence.

Some highly motivated operators continue to the third stage of the competency continuum. Here they develop an understanding of parameter relationships and qualitative analysis for common processes, such as distillation. It is at this stage that the operators can answer questions such as "If the bottoms temperature increases, then the impact throughout the column will be ___." Advanced operators continue to the fourth and fifth stages of the continuum. In the fourth stage, they develop the ability to systematically link multiple processes and qualitatively analyze an entire unit. In the final stage, they add the ability to systematically analyze the unit with both magnitude and rate of change for their specific unit and its unique operating envelope. It is this capacity to systematically analyze unit operations that enhances safety and operational effectiveness.

The studies conducted by GP Strategies[1] indicate that the average operator competency level is about 30 percent of the maximum attainable (Stage 2) and that it often takes over 10 years before competency reaches 70 percent (Stage 4 of the model). This, combined with high attrition rates for experienced operators, makes it difficult to achieve operational goals.

A Better Way to Learn

To address the shortcomings in process unit operational competency, GP Strategies combined its process industry experience with its understanding of the factors impacting human performance and state-of-the-art instructional interventions to create the PlantMentor suite of courseware.

From an instructional perspective, GP Strategies looked outside the process industries to the medical profession. In examining how new doctors developed their competency, GP Strategies uncovered a "simple to complex" learning model of instruction that relied on four factors. Doctor candidates:

- Complete a curriculum in medical school to learn about the physiology of the human body. They learn about various organs and systems, such as the muscular-skeletal and circulatory systems.
- Learn to think systematically about illnesses, to observe carefully, and to not overlook trivial symptoms. This rigorous focus on identifying symptoms and the process of diagnosis is critical.
- Undergo an extensive period of training as interns, in parallel with their academic studies. During this phase of their training, doctor candidates learn to apply their knowledge of the human body to the real world. The common model is for a number of interns to be assigned to a highly qualified doctor where they accompany the doctor in treating patients. There are two very important concepts in this phase of training:
  - The interns are afforded the opportunity to see many patients from all parts of the demographic spectrum and to see how various diseases and injuries manifest themselves in individuals from a wide variety of racial, socioeconomic, age, and other backgrounds.
  - The interns are instructed using a Socratic, or question-dialog, learning model. The instructor doctor might ask the interns a question like "Mr. Jones has kidney stones. How would you expect his kidney stone issue to be manifested– what symptoms would you expect to see?" They would be expected to apply their knowledge of the human body to determine what symptoms should be present. They receive input and feedback from each other, the question-dialog process reinforces correct responses and ensures proper analysis, and they develop a deeper understanding of each symptom and how and why it is present. The interns are exercising their ability to diagnose illnesses by answering the instructor doctor's question in a systematic way: "With kidney stones, Mr. Jones should have a high temperature, abdominal pain, etc." They then determine whether or not all of the symptoms are present.
- Apply their knowledge and systems thinking by looking for symptoms in patients and diagnosing the underlying illnesses as residents. This process flips the third phase around. Residents examine and interview patients to determine their symptoms, and they order tests to uncover symptoms that may not be outwardly apparent. With a full picture of the symptoms, the residents work through a process of mental simulation. They quickly discard diseases and injuries that obviously do not apply and then begin working through a decision tree analysis process: "I see the following symptoms: XXX, YYY, and ZZZ. Mr. Jones might have a kidney stone issue. If it were a kidney stone issue, I would expect to see the following symptoms…." The resident confirms that the symptoms are present and, if necessary, orders additional tests to confirm the hypothesis. If some of the symptoms are not present, then the resident formulates a new hypothesis. This emphasis on rigorous and methodical diagnosis ensures all symptoms are examined and "accounted for" and dramatically improves the diagnosis quality.

GP Strategies' examination of the method by which doctors are trained fit the process industries exactly as well. Application of a similar process could significantly improve the ability of operators to troubleshoot their units, to improve production, and to reduce risk. Based on this research and thinking, GP Strategies developed an instructional model for operators that emphasized:

- Teaching operators systematically about units and the means by which the units are controlled.
- Applying a streamlined, yet rigorous and repeatable troubleshooting methodology.
- Developing competency through a questioning-dialog process – emphasizing "what-if" thinking to deepen individual and collective understanding of all aspects of the operation.
- Applying the new competency by exercising it through complex problem solving and feedback.

PlantMentor Design Basis

PlantMentor is the registered brand name for a suite of Web-based eLearning courses that support operator training and certification in refineries, petrochemical plants, and chemical facilities. Interactive learning and exercises employed in the PlantMentor approach make the courses powerful "hands on" training tools that enable skill building, accelerated competency, and mastery of complex technical knowledge and decision-making capabilities.

The instructional approach described in the previous section guides students along a competency path that significantly improves their process unit knowledge. At the same time, students learn the troubleshooting/analysis approach to which they will apply their new knowledge. This approach, depicted in Figure 2, is conceptually similar to the process that doctors use to diagnose patients.

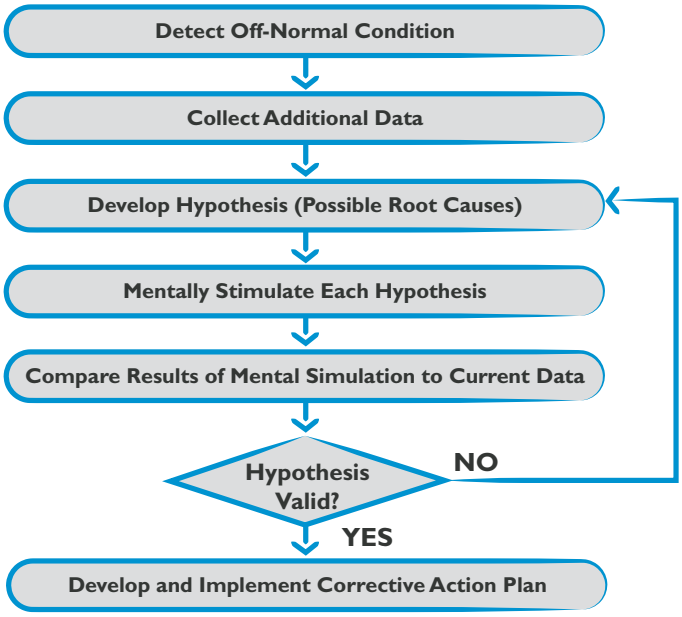

Figure 2: PlantMentor Troubleshooting Model

PlantMentor utilizes a completely modular, building-block approach that guides operators through a learning progression to develop within them a consistently high level of unit competency. The courses build on the instructional model described previously to develop within operators a standardized approach to troubleshooting / unit optimization based on a common, shared understanding of the unit and how it operates — a simple concept that rarely exists prior to a PlantMentor implementation. The result is an improvement in safety, risk reduction, and improved unit operations. PlantMentor represents a quantum improvement in process unit operational training because it leverages technology to deliver superior training value.

As Figure 3 illustrates, each four-module course guides students through progressively more difficult concepts, with the final module focusing on troubleshooting and optimization problems. To complete each module, students must pass an assessment before proceeding to the next module. Module 3 and Module 4 of each course contain complex exercises that exercise and reinforce the previously-learned knowledge and systems thinking.

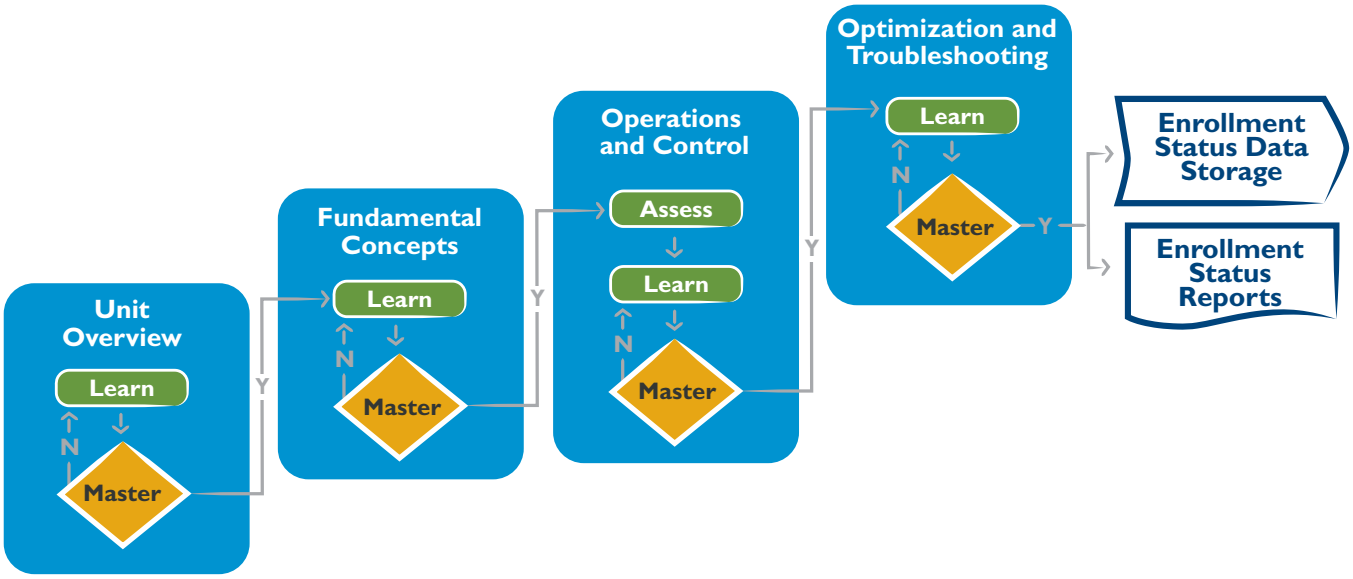

Figure 3: PlantMentor Course Design

Each PlantMentor module is completely standalone, meaning that it can be completed as an individual learning object or as part of the broader course. This affords organizations a new capability to support "life-cycle learning" in which:

- Brand new operators might complete the Unit Overview module to learn about typical refinery processes when they first join the organization.
- Operators in training might complete the Fundamental Concepts module to master basic refinery processes as part of an Initial Operator Qualification program.
- Experienced operators might complete the Operations and Control module either as a console operator selection mechanism or as part of an Advanced Operator Qualification program.
- Console operators might complete the Optimization and Troubleshooting module to develop their advanced operations and troubleshooting skills as part of a Console Operator Qualification program.

This "life-cycle learning" approach is depicted in the following figure, overlayed on top of the Operational Performance Competence Model described earlier.

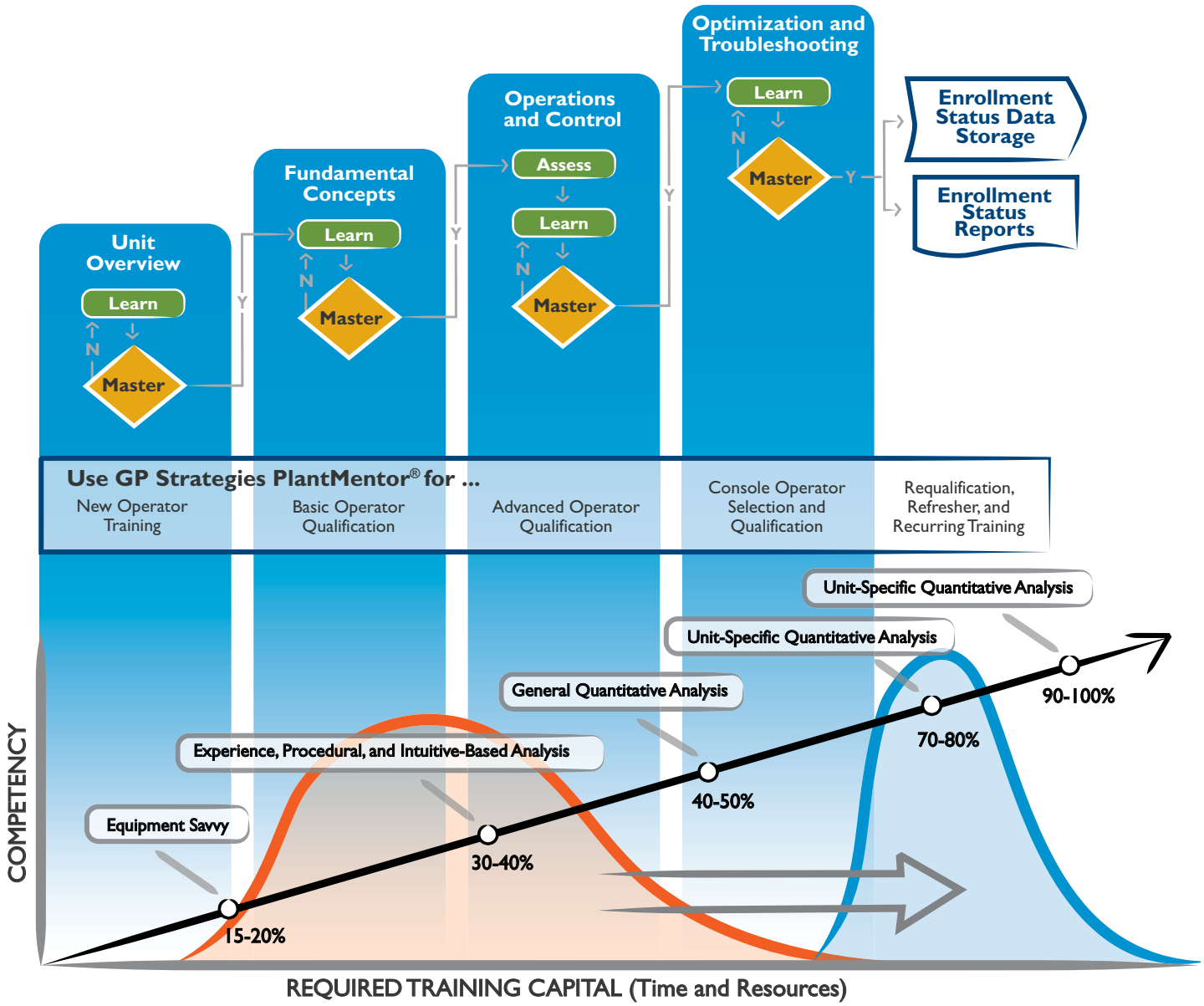

Figure 4: PlantMentor Life-Cycle Learning Approach

Let there be no doubt – PlantMentor courses are extremely challenging. But students also find the courses to be very valuable because the courses address a deeper level of understanding and competency that has been lost over time. Courses require students to think logically and to reason their way through problem scenarios instead of relying on experience-based knowledge.

In architecting the PlantMentor courseware, GP Strategies also considered how the courses should be delivered. The modular nature of the courses, and the time required to complete them, suggested that a self-paced eLearning delivery strategy would be most applicable. GP Strategies then considered the broader eLearning industry and determined that the courses should conform to the eLearning requirements specified by the SCORM standard[2]. At the same time, GP Strategies recognized that the SCORM standards are not static. In fact, there has been a significant upgrade in the SCORM standard with the release of SCORM 2004 (sometimes referred to as SCORM 1.3) compared to the most commonly referenced SCORM 1.2. PlantMentor has been designed to conform to both versions of the SCORM standard.

PlantMentor Features

Technically, complex elearning courses tend to be very text-driven. Recognizing this, GP Strategies took every opportunity to engage learners through the use of animation, mouse-overs, pop-ups, and knowledge checks. In fact, it is almost impossible to progress through more than four pages in any module without encountering a knowledge check. The following two figures depict two of the many forms of interactivity that have been incorporated into the courseware.

To further engage learners, and recognizing that different learners possess different learning styles, GP Strategies has included full narration and narration transcripts in the courses. Learners possessing a more auditory learning style can rest assured that their needs have been considered.

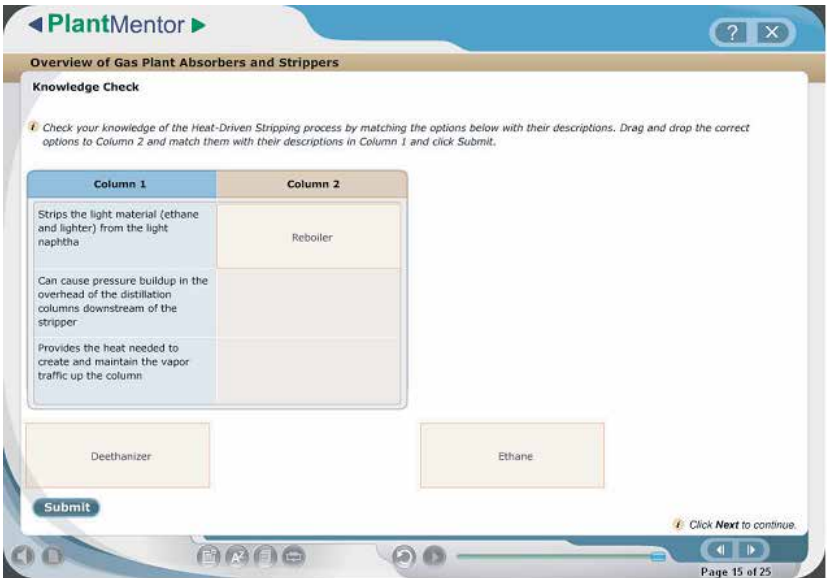

Figure 5: PlantMentor Interactivity – Knowledge Check

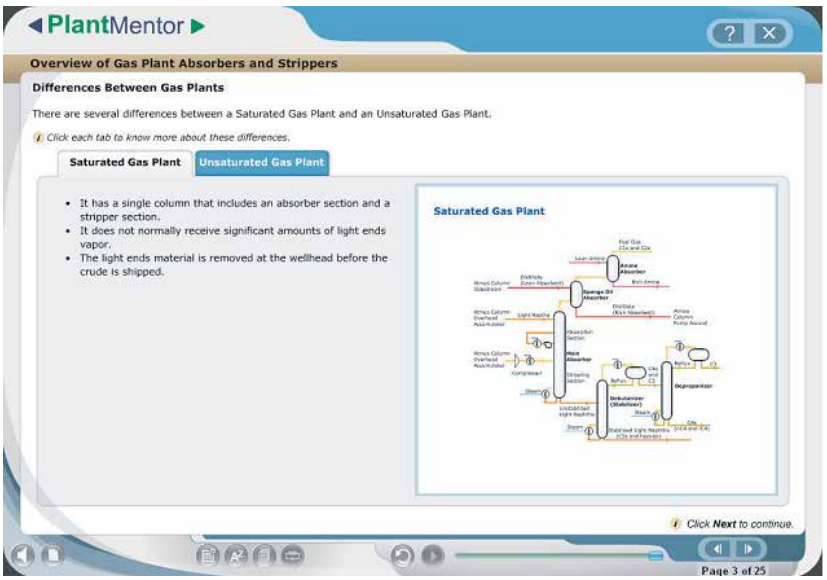

Figure 6: PlantMentor Interactivity – Interactive Elements

PlantMentor Courses

The curriculum includes the following PlantMentor courses:

- Amine Loops
- Crude Unit Distillation
- Delayed Coking
- FCCU Main Column
- FCCU Reactor-Regenerator
- Gas Plant Absorbers and Strippers
- Hydrogen Reforming
- Hydrotreating
- Isomerization
- Light Ends Distillation
- Semi-Regen Reforming
- Sulfur Recovery Unit
- Sulfuric Acid Alkylation
- Tail Gas Unit

PlantMentor Benefits

Training Perspective

PlantMentor was designed to accelerate time-to-competency and to improve operator competency. When used as part of a broader operator qualification program, PlantMentor courses can also help bridge the gap between training and on-the-job performance. With these goals in mind, the following PlantMentor training benefits quickly become apparent:

- Reduce time-to-competency; i.e., shortening the time to achieve on-the-job effectiveness.
- Improve training productivity – by taking advantage of "free time" and by eliminating the constraints associated with "classroom session time."
- Allow students the convenience of progressing through the courses at their own pace.
- Deliver better learning through highly structured interactive learning and exercises.
- Emphasize rigorous instructional design, with clear learning objectives and embedded "knowledge checks to give the learner constant feedback."
- Utilize extremely effective and highly technical training content – even the most competent incumbents will gain additional proficiency from exposure to this unique training experience.

Business Perspective

PlantMentor represents a sound financial investment as well. The results from an analysis by the Glomark Corporation[3] suggest compelling, quantifiable business benefits.

Table 1 presents an expected value analysis for implementing PlantMentor for two FCCUs at a refinery site in the Midwest region of the United States. The Glomark analysis is based on data obtained from experts at this site.

As is evident from the results, the value proposition for investment in PlantMentor is compelling, and PlantMentor users should recover the investment cost quite rapidly.

Table 1: PlantMentor Expected Value Analysis (6-Year Cumulative)

	BEST CASE	LIKELY CASE	WORST CASE
Simple ROI	3,147%	1,145%	127%
Payback	4 months	4 months	7 months
Added Value	$22,664,630	$6,184,467	$515,107

The results presented in Table 1 were generated from a 6-year value analysis in the following categories:

- Improved process efficiencies
- Improved recovery time
- Improved training productivity
- Reduced environmental incidents
- Reduced process downtime
- Reduced process engineering costs

In addition to the Glomark results, other business benefits include:

- Safer and less risky operations
- Improved ROI
- Improved skills for executing operational and recovery procedures
- Improved Operations ability to avoid accidents and environmental incidents
- Improved troubleshooting skills, helping operators determine the best upset recovery strategy more quickly – resulting in less disruption of production goals
- Improved optimization skills, maximizing the time that the unit runs at optimum levels within the acceptable process parameter ranges.
- Helps bring all personnel to the same competency level of the most accomplished performers
- Helps to turn accomplished performers into exceptional performers

Summary

PlantMentor was designed to address the compelling safety and operational performance needs of the process industries. Operators who complete the courses develop a new level of competency that greatly enhances both their individual capabilities and their value to the organization.

While the benefits of achieving higher levels of performance are evident, the results of Glomark's analysis support the business case for PlantMentor implementation. These results suggest that implementation benefits can improve performance during both normal and abnormal operating conditions.

The petroleum-chemical industry is capital intensive, highly regulated, and incredibly intolerant of operational errors. A single operational excursion can result in millions of dollars in equipment damage, fines, civil penalties, adverse publicity, or other sanctions. Anything organizations can do to significantly reduce or eliminate human performance errors on the part of those personnel operating and controlling the process units will doubtless reduce the frequency and impact of a potential error.

The essence of risk mitigation is that it attempts to balance frequency and consequence. In the petroleum-chemical industry, accidents and incidents tend to occur infrequently, but their consequence is invariably severe. PlantMentor helps organizations reduce both the frequency and the consequence. ■

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Notes:

[1] GP Strategies tested over 450 incumbent Console Operators and Console Operator Candidates across more than 10 refineries for competency in troubleshooting and advanced unit analysis. Test results clearly indicated a strong clustering of competency around experience, procedural, and intuitive-based analysis with few "star performers" demonstrating competency at the General Qualitative Analysis level.

[2] SCORM, or Shareable Content Object Reference Model refers to the Advanced Distributed Learning's (ADL's) standard for eLearning content and Learning Management Systems (LMS). Conformance to the standard ensures that the courses are "portable" and can be installed, launched, and tracked using any LMS that conforms to the SCORM standard.

[3] Glomark Corporation helps technology and service providers to implement an economic value selling approach and helps technology and service buyers to forecast, compare, and track the economic value of investments/projects.

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