USING PERFORMANCE OBJECTIVES TO DIFFERENTIATE LEVELS OF SKILL DIFFICULTY

The Problem

"Sure we teach the task in the Level 1 course, but the fact is, it takes months, even years to get really good at it."

I hear this type of comment a lot. There is a mixture of skepticism and frustration behind the comment. Skepticism over the significance of a performance-based "sign-off" in the "Level 1" course. Frustration over how to differentiate levels of expertise.

Concern is also expressed when developing a customer support engineer (CSE) certification program. Those exploring this wonder:

- Would it help to distinguish the skill levels of CSEs with words like: competent vs. expert? Or junior vs. senior? Or master vs. guru?
- Is the differentiating factor the *total number* of tasks that varying CSEs can perform? Or is it the same number of tasks for all CSEs, but with language that differentiates the varying level of *quality* that each CSE delivers any given task?
- Given the vagaries of the options so far (first two bullets), how will we proceed to qualify or certify our CSEs on the tasks for our equipment?

In this article I will explain how part of the solution, indeed the foundation to the solution, lies in how the initial analysis is done and how performance objectives are written.

Background Information Notice

To get full value in what I will propose in this article, you will need a background in the following PBET topics, and especially the first two (fortunately there are Solid Performance Solutions –SPS– Bulletins of those first two topics):

- The PBET process (or the performance improvement process).
- The parts of performance objectives.
- Editing performance objectives.
- Interpreting a learning hierarchy.

A Common Error

Before explaining how performance objectives can be used to help clear the clouds of skill level uncertainty, lets look at a common approach that can lead to difficulty, namely– *having one objective that covers all aspects of a single task.*

What is this, and how does it happen?

At the beginning of the analysis stage of PBET, it is common to establish a list of tasks. There are several ways to do this including job analysis and equipment analysis. Regarding the latter, I have been heard to urge, "Consider all the tasks that anyone would need to do, on one machine." By that I encourage those involved to forget about job titles. Focus on machine modules and assemblies and ask *What are all the tasks associated with this module or assembly?- any and all tasks of operation, maintenance, repair, installation, adjustment, etc.*

Consider some tasks that might be listed (among dozens or hundreds, depending on machine size and complexity):

- Operate the machine.
- Clear error messages.
- Check and adjust the elevator height.
- Correct blower failures.

Should these tasks be broken down into multiple objectives? Yes, in most cases, especially in more complex machines. Otherwise, we will be stymied when we try to determine the correct "skill level" for these tasks. So beware of having one objective that is presumed to cover one task, but for which there will be varying reasons for subdividing the task into two or more objectives.

Example #1: Operate the Machine / Generate a Stable Ion Beam

Let's look more closely at the above short list of tasks, beginning with "Operate the machine." To illustrate, let's use an ion implanter, a complex machine used in the doping process of semiconductor fabrication. Operating an ion implanter includes several aspects, including the generation of an ion beam of a selected dopant material, or species. For this illustration we will focus on the task of beam generation, or, ***generate a stable ion beam***.

Notice how slight variations in the parts of the objective impact the skill difficulty. To help you make sense of it, please note:

- A sample learning hierarchy for these seven sample objectives appears on page 6.
- Sample objectives "A," "B," and "C" are all examples of beam generation in *auto mode.*
- Sample objectives "D," through "G" are all examples of beam generation in *manual mode.*

Example #1: Generate a stable ion beam.			
#	OBJECTIVE	COMMENTS	CONCLUSION
1A	Given: • A Model XYZ fully functioning ion implanter at "Control Power On and Ready" with an installed bottle of argon, and • The Model XYZ Operation Manual, **Generate a stable ion beam of argon in auto mode.** Standards: • Each step of the Manual Beam Generation procedure in the Operation Manual must be followed exactly. • When done, the system controller should display, "Ready for Implant."	Argon (a non-production species) is a non-toxic gas. It is not used for production purposes, but is used for certain maintenance procedures. It is because it is non-toxic that it is often used for training purposes when learning to operate an implanter. Equipment supplier training centers typically use *only* argon for training. Note also that the task is done *in auto mode,* with the procedure available. Altogether, an easy task. Target audience: • *Definitely* – fab operators – an external audience group • *Definitely* – maintenance engineers and process engineers – external audience groups • *Definitely* – customer support engineers (CSEs) – an internal audience group Training venues: • Equipment supplier training center • Customer fab	This objective would be included in a Level 1 course taught by the equipment supplier. All members of the target audience would start with this course.

#	OBJECTIVE	COMMENTS	CONCLUSION
1B	Given: • A Model XYZ fully functioning ion implanter at "Control Power On and Ready" with installed bottles of aaaa, bbbb*, and argon, • A list of ##* sets of implant parameters for each production species, and • The Model XYZ Operation Manual, **Generate a stable ion beam for all listed sets of implant parameters in auto mode.** Standards: • Each step of the Manual Beam Generation procedure in the Operation Manual must be followed exactly, each time. • When done for each species, the system controller should display, "Ready for Implant." *NOTES: *"aaaa and bbbb"* = the actual species used for implants at the respective fab performer's work area. *"##"* = the actual number of sets of implant parameters required at the respective fab performer's work area.	This is most like "A" above except that the performer must generate ion beams *using production gases they are required to use on their job.* As stated above, equipment suppliers typically use *only* argon during training at their training centers for safety reasons. This objective thus comes closer to the actual task required by real operators and maintenance engineers in fabs. Note also that the task is done *in auto mode,* with the procedure available. Altogether, still a reasonably easy task. The objective is well suited as a follow-up to "A" above, one that would be customized to the situation of the trainee's fab. Target audience: • *Definitely* – fab operators – an external audience group • *Definitely* – maintenance engineers and process engineers – external audience groups The training for this objective could be conducted by either … • A lead operator or fab trainer from the customer fab, *or* • An equipment supplier trainer or CSE onsite at the customer fab.	This is a Level 1 objective for customers (operators, maintenance engineers, etc.) but would not be included in an open enrollment, equipment supplier course. Instead it would be taught by the customer's own trainers or lead operators. *OR* It could be taught by the supplier's trainer as part of a Level 1 *custom designed onsite* course.
1C	Given: • A Model XYZ fully functioning ion implanter at "Control Power On and Ready" with installed bottles of boron trifluoride (BF3), arsine (ASH3), and argon, • A list of 2 sets of implant parameters for each production species, and • The Model XYZ Operation Manual, **Generate a stable ion beam for all four sets of implant parameters in auto mode.** Standards: • Each step of the Manual Beam Generation procedure in the Operation Manual must be followed exactly, each time. • When done for each species, the system controller should display, "Ready for Implant."	This is just like "B" above except that the focus is on customer support engineers (CSEs). CSEs need ability to operate equipment they would encounter at a variety of customer sites. So the objective focuses on the most commonly used gas species. Target audience: • *Definitely* – customer support engineers (CSEs) – an internal audience group Training venues: • Equipment supplier process lab • "Field training" with senior CSE at customer fab	This is a Level 1 objective for CSE's. It would be a Level 1 objective but not "signed off" in the Level 1 *course*. It would need to be "signed off" later. For example, • At the suppliers process lab by process engineers or by senior CSEs. *OR* • At the customer fab by mentoring senior CSEs.

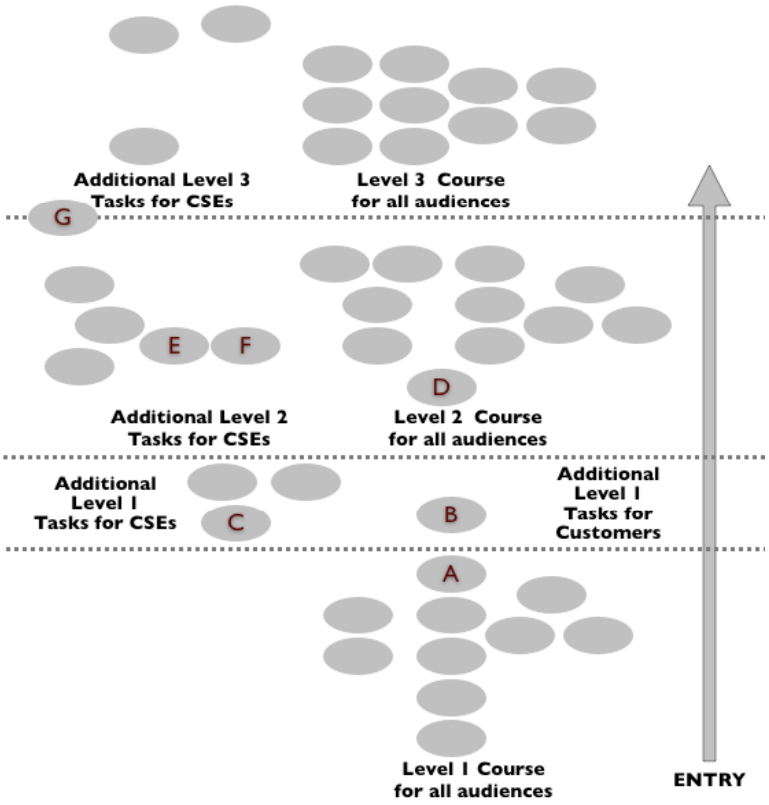
#	OBJECTIVE	COMMENTS	CONCLUSION
1D	Given: • A Model XYZ fully functioning ion implanter at "Control Power On and Ready" with an installed bottle of argon, and • The Model XYZ Operation Manual, **Generate a stable ion beam of argon in manual mode.** Standards: • Each step of the Manual Beam Generation procedure in the Operation Manual must be followed exactly. • When done and when queried, the system controller should display, "Ready for Implant."	The only difference (compared to Objective "A" above) is that the task is to be done *in manual mode.* The performer still gets to use the Manual It requires greater understanding than auto mode. Manual control of operation is typically used by maintenance to troubleshoot or verify certain correct procedures. Target audience: (Not for operators) • *Definitely* – maintenance engineers – external audience group • *Possibly* – process engineers – external audience group • *Definitely* – customer support engineers (CSEs) – an internal audience group Training venues: • Equipment supplier training center • Customer fab	This objective would be included in a Level 2 course taught by the equipment supplier. This is due to the use of manual mode.
1E	Given: • A Model XYZ fully functioning ion implanter at "Control Power On and Ready" with an installed bottle of argon, and • Using no references, **Generate a stable ion beam of argon in manual mode.** Standards: • Each step of the Manual Beam Generation procedure in the Operation Manual must be followed exactly. • When done and when queried, the system controller should display, "Ready for Implant." • The time required should be no more than 3 minutes from "Control Power On and Ready" to the "Ready for Implant" message.	This is the same as Objective "D" above except that it is a bit more difficult to do: the task must be memorized ("no references") and must be done under a time limit of 3 minutes. The "3 minutes" is not arbitrary; it is the time expected of senior customer service engineers (CSEs), validated from analysis of six senior CSEs. The task would require somewhat more practice, either in class or subsequent to the formal training class. Target audience: (Not for operators) • *Possibly* – maintenance engineers – external audience group • *Possibly* – process engineers – external audience group • *Definitely* – customer support engineers (CSEs) – an internal audience group Training venues: • Equipment supplier training center • Customer fab	This is still a Level 2 objective, although a bit advanced (higher than Objective "D.") However, there are different possible scenarios given differing job descriptions and the need for extended practice: • Group class for maintenance and CSEs • Group class for process engineers • One on one mentoring in fab • One on one mentoring in supplier training center or process lab

#	OBJECTIVE	COMMENTS	CONCLUSION
1F	Given: • A Model XYZ fully functioning ion implanter at "Control Power On and Ready" with installed bottles of boron trifluoride (BF3), arsine (ASH3), and argon, • A list of 2 sets of implant parameters for each production species, and • The Model XYZ Operation Manual, **Generate a stable ion beam for all four sets of implant parameters in manual mode.** Standards: • Each step of the Manual Beam Generation procedure in the Operation Manual must be followed exactly, each time. • When done for each species, the system controller should display, "Ready for Implant."	This is the same as "C" above except that it now requires manual mode. Again, the focus is on customer support engineers (CSEs). Again, as already stated, CSEs need ability to operate equipment they would encounter at a variety of customer sites. So the objective focuses on the most commonly used gas species. Target audience: • *Definitely* – CSEs – an internal audience group Training venues: • Equipment supplier process lab • "Field training" with senior CSE at customer fab	This is a Level 2 objective, because of manual mode. Following Objective "D," an individual CSE could work on either "E" or "F" – it wouldn't hurt or help either way.
1G	Given: • A Model XYZ fully functioning ion implanter at "Control Power On and Ready" with installed bottles of boron trifluoride (BF3), arsine (ASH3), phosphine (PH3), and argon, • A list of at least 2 sets of implant parameters for each production species, and • Using no references, **Generate a stable ion beam for all four sets of implant parameters in manual mode.** Standards: • Each step of the Manual Beam Generation procedure in the Operation Manual must be followed exactly, each time. • When done for each species and when queried, the system controller should display, "Ready for Implant." • The time required for each set of parameters of production gases, once the system has been purged, should be no more than 6 minutes from "Control Power On and Ready" to the "Ready for Implant" message.	This objective is meant to demonstrate an advanced level of expertise regarding the task of beam generation during machine operation. • The task includes using *all* likely implant gases (revise list to reality) that a CSE might encounter at *any* customer site. • The task is expected to be done from memory (no references). • The task is expected to be done at a speed that meets the level of expertise of other senior CSEs as determined through analysis. The combination of working from memory *and* quickly is to suggest that it be done fluently (automatically, with little thought). Target audience: • *Definitely* - customer support engineers (CSEs) Training venues: • Equipment supplier process lab • "Field training" with senior CSE at customer fab	This could be viewed as: • A Level 2 task for CSEs — it is more advanced than Objective "F" and is taught after Objective "F." However it is does not require much additional knowledge, mostly additional practice (experience). *OR* • A Level 3 or higher task — the very fact of the far greater amount of practice (experience) dictates that it is a higher level objective. This is more a matter of definition of levels.

The sample objectives in this hypothetical study are not meant to be

- Exhaustive — no doubt there can be others!
- Prescriptive — your situation will vary. Analysis of your situation determines actual tasks → actual objectives → actual learning hierarchy.

With that in mind, let's see how this would look on a machine skills learning hierarchy. Well, sort of – we won't be showing the whole hierarchy, just the rough placement for sample objectives "A" through "G" above.



The "Additional Level 1 Tasks" area on the map may surprise you. It is meant to indicate a continuation of the Level 1 hierarchy but at the same time, they are tasks not taught as part of the ***standard*** equipment supplier's Level 1 ***customer*** course. The reason is explained in the comments section of the objectives table.

Another thing: when listing "all the tasks associated with one machine" at the start of the analysis process, we did not limit ourselves by saying "Oh, that's not something we teach to customers." We listed all the tasks! Is that how we ended up with seven variations on "generate an ion beam"? Maybe. Using that process, at first we likely had only two: generate an ion beam in auto mode and generate a beam in manual mode. It may well have been later, as we put the hierarchy together, that we began to realize that, in order to accommodate the needs of the various learners, we would need to detail the tasks with conditions and standards appropriate to the circumstances of the different learners (workers).

The conditions and standards for a customer's maintenance engineer and a supplier's CSE will at times be different. Doesn't that make sense?

Had we focused more on job analysis during the analysis phase, we would have figured this out before getting to the hierarchy. For the most part, equipment suppliers often gloss over a formal job analysis because (a) it is difficult to find expert performers when dealing with a new product, (b) it is difficult to get access to our customer's workers, and (c) it is time consuming.

But just because we don't actually do a job analysis, and often substitute it with an equipment analysis, that doesn't mean we can ignore the differing conditions and standards for the many performers we want to help, both external and internal. No matter what, we find ourselves forced to do some analysis of *what these jobs actually require.*

Finally, in the ion beam generation example, did you notice that our tasks included some that are taught in formal training courses and others that are not part of formal courses? Tasks taught in courses are signed off by the course instructor. Other tasks are subsequently signed off by various mentors like senior CSEs, lead operators in a fab, or supervisors. All mentors and supervisors should be given instruction on PBET basics so that they can properly interpret objectives, understand the proper use of feedback, and are acquainted with the sign-off procedure established by their respective companies.

Example #2: Clear Error Messages

Most machines produce error messages that need to be cleared. Is that the basis of an objective and lesson? If so, it is probably at the end of a Level 3 (or higher) course! Imagine all that you would need to know and do to clear ***every*** error message!

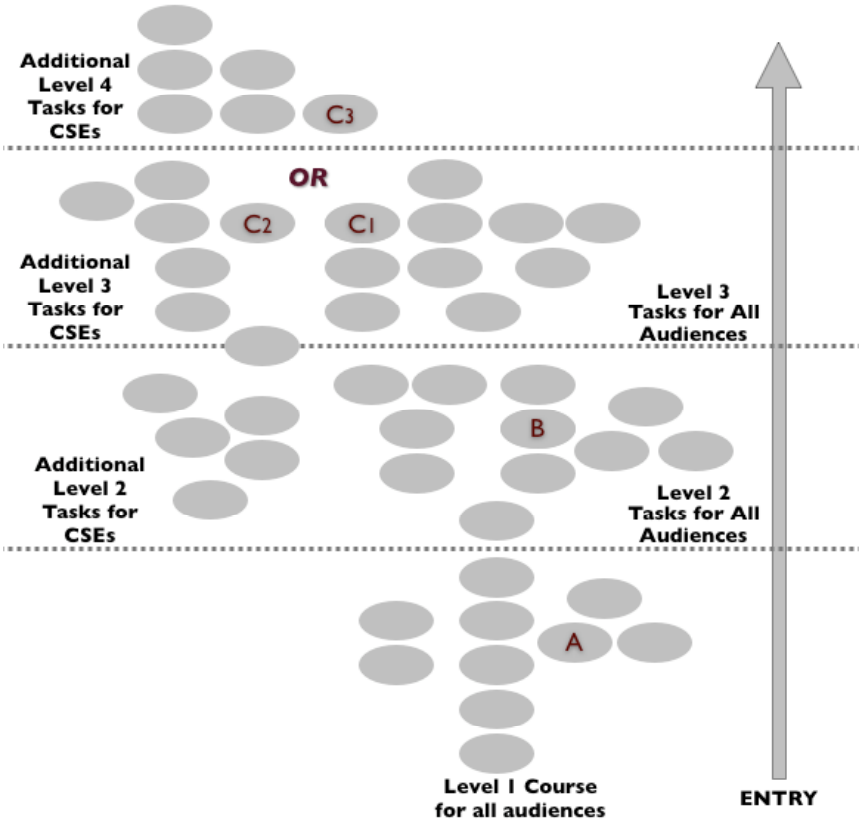
But wait, are there a few error messages that operators are expected to clear? Typically, the answer is yes. In the end, it is generally useful to take a task like "clear error messages" and break it into pieces so that the right portions are taught to the right target audiences in the most useful sequence. For example:

- What does "clear" mean or include? Identify? Interpret? Diagnose? Follow a procedure?
- How does the scope change for different target audiences? That is, how many errors are different groups responsible for?
- What will I need to know or do in order to clear any specific message? You will need a list of all messages. (Good luck!)

This is just suggestive; *your* machines and target audiences will likely result in *different* objectives and levels:

Example #2: Clear error messages.			
#	OBJECTIVE	COMMENTS	CONCLUSION
2A	Given: • A Model XYZ reflow oven displaying any one of 8 possible operator error messages, and • The Operation Level Errors Table, **Clear the error message.** Standards: • Each step for clearing an error listed in the Operation Level Errors Table must be followed exactly. • When done, no operator error message should display.	This objective focuses on a very small select group of error messages and the simple procedures for clearing them. Target audience: • *Definitely* – operators – external audience group. • *Definitely* – maintenance engineers – external audience group. • *Possibly* – process engineers – external audience group. • *Definitely* – customer support engineers (CSEs) – an internal audience group. Training venues: • Equipment supplier training center. • Customer fab.	This is a Level 1 objective, necessary for most everyone learning to work on the reflow oven.
2B	Given: • A Model XYZ reflow oven displaying "Spatial Over Temperature" message, and • The XYZ Operation and Maintenance Manuals, **Clear the error message.** Standards: • Each step for clearing an error listed in the Operation Level Errors Table must be followed exactly. • When done, the "Spatial Over Temperature" message should no longer display.	This objective focuses on a single error message which has, as one possible fix, to replace a capillary. Performing the task requires following the instructions in the table and, if replacement is needed, the capillary replacement procedure. Target audience: • *Definitely* – maintenance engineers – external audience group. • *Definitely* – customer support engineers (CSEs) – an internal audience group. Training venues: • Equipment supplier training center. • Customer fab.	This is a Level 2 objective.

#	OBJECTIVE	COMMENTS	CONCLUSION
2C	Given: • A Model XYZ reflow oven displaying "No Communication With Oven" message, and • The XYZ Operation and Maintenance Manuals, **Diagnose and clear the error message.** Standards: • The "Troubleshooting Guide" in the Maintenance Manual should be followed while diagnosing the fault. • When done, the "No Communication With Oven" message should no longer display.	This objective focuses on a single error message which requires diagnosing electronics and use of schematics with multiple possible causes. Target audience: • *Possibly* – maintenance engineers – external audience group – *See the hierarchy below and the "Note" underneath.* • *Definitely* – customer support engineers. (CSEs) – an internal audience group. Training venues: • Equipment supplier training center. • Customer fab – depends.	This is a Level 3 objective.



Note: Perhaps Task C is taught to customers (C_1). ***Or,*** Task C ***might*** be one of those tasks that, for whatever reason (infrequency? complexity? embarrassed by such faults?), your company decides that it will *not* be taught to customers. In that case there are two equally good choices: (a) move the task over to the "CSE side" of the hierarchy (C_2), or (b) move the task up to a level reserved exclusively for CSE type tasks (C_3). In my mind, choice C_2 suggests that the task is on a Level 3 with regard to difficulty or complexity, but due to infrequency of the task, it is pointless to include as standard customer training. Using choice C_3 suggests a task that is both infrequent *and* on a higher level of complexity. However, either choice works no matter what rationale you have, as long as it is not intended for customers (given the vague level definitions shown above).

Example #3: Check and Adjust the Elevator

The list of all the tasks on your machine will likely have a certain number *like* "Check and adjust the elevator height." Here are some possibilities to consider:

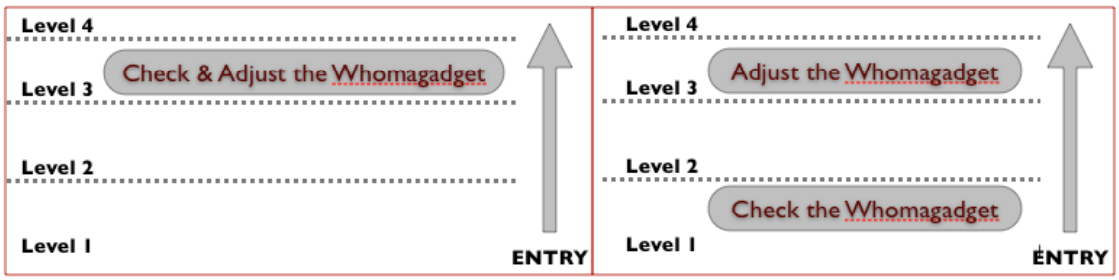
Who would be expected to do this task? Specifically, is the check part of the *same technical complexity* as the adjust part? Or are these two tasks of different complexities – the check being such that an operator could do it and the adjust requiring a maintenance engineer?

A. If both are of the same complexity, keep it as one objective. Depending on difficulty (or job description) it could be one objective on any level.
B. If the check is much easier than the adjustment, consider splitting the objective into two objectives.

What type of access is required to perform the "check"?

A. If the assembly parts must be removed from the machine in order to perform the check, indeed the same parts that must be removed to perform any adjustments, then keep the "Check and adjust" as one task, typically at Level 2 or 3.
B. If the check can be done without removing any parts, it *may* be best to separate the tasks. Why? Different customers will have differing ideas about what tasks should be done by whom. For example, sometimes operators do certain *checks* (although not the adjustments) whereas, at other customer sites, the checks are performed by maintenance techs who also do the adjustments. By creating two separate objectives, you are prepared to customize to their requirements. So, even if the adjustment is a Level 3 objective (or higher), -
    - If the check for it is done by reading a screen or gauge, then the check would probably be a Level 1 objective
    - If the check for it requires taking a measurement with a tool like a voltmeter or calipers, then the check would probably be a Level 2 objective.

Example #3: Check and adjust the whomagadget.



A. One Objective **B. Two Objectives**

Is it possible to group some checks (without adjustments) into a single task? Here is one example: Perform the daily machine readiness checkout. The checkout might have eight items that have been combined into one list. Just make sure, when doing that, that every one of the checks will still make sense when you look at the items that come before it and after it in the hierarchy.

Example #4: Correct Blower Failures

Keep in mind that very often specific (yet separate) sub-tasks can make up a more general task. The sub-tasks my fall into different levels. This is why it is easier if you make every effort to think of *as many of the machine tasks as possible* before trying to create a learning hierarchy.

"Correct Blower Failures" illustrates the idea of sub-tasks scattered into different levels.

Example #4: Correct blower failures.	
SUB TASKS	COMMENTS
4A Replace a blower motor.	Here is a mechanical task that ordinarily might be placed into Level 2 without thought. Yet, the reality is that in several companies, operators perform this task. Thus some equipment suppliers have placed it into Level 1,… actually, near the *top* of the Level 1 hierarchy.
4B Verify that blower functions at high, medium, and low speeds.	This is considered a check only. It was placed into Level 2. See 4C for the task that results if verification fails.
4C Diagnose errors of low, medium, and high blower speed.	This troubleshooting task was placed into Level 3. This is the task required if the "Verify" check (above 4B) fails.
4D Align the blower axis.	This is a task that is *rarely performed*. Normally, the unit would be replaced. In one equipment supplier company, only two people in the entire organization knew how to do this. They placed this task in Level 5. (Level 5 was reserved for tasks that this supplier would never teach to customers, and rarely if ever even teach internally. It was a vendor issue.)

Now, add to the idea of these sub-tasks, the potential for varying conditions or standards of quality expected (go back to Example #1) and you can envision further scattering of the task into different levels.

Conclusion

It may be of interest to see that different suppliers use different leveling schemes, as has already been alluded to. Some schemes have three levels, some four, and a few companies have schemes with more than four levels.

Some information on how the levels may be defined is provided on page 11.

However, the purpose of this paper is not to present a definition of the levels.

The purpose of this paper has been to demonstrate how **careful analysis, followed by the crafting of well-written objectives facilitates placing the tasks into whatever leveling scheme you choose to adapt.**

Richard Goutal, Owner and Workshop Leader
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OF INTEREST: Different Skill Level Schemes

LEVEL	SEMATECH (TTC 2002 Report – Guidelines Page 6)	SEMATECH (TTC 2002 Report – Generic Task Levels Page 14)	EXAMPLE COMPANY 1	EXAMPLE COMPANY 2
5	- - - NA - - -	- - - NA - - -	*Extremely rare tasks*	- - - NA - - -
4	Ability to resolve basic factory automation and tool connectivity or process issues.	- - - NA - - -	*Tasks Reserved for Supplier CSE*	- - - NA - - -
3	Ability to resolve corrective actions.	*Advanced Tasks:* Major Corrective Maintenance Major Calibration Troubleshooting Problem Diagnosis Cause Recognition Tool Optimization Failure Analysis Machine Process Interaction Installation	*Selected/Senior Maintenance Tasks* • Troubleshooting • Advanced Repair	Complex tasks that are non-routine and require a high level of background knowledge and independent judgment.
2	Ability to perform routine PMs, tool calibrations, and subsystem specific repair and maintenance.	*Intermediate Tasks:* • Advanced Operations • Advanced Preventive Maintenance • Minor Corrective Maintenance • Minor Calibration • Advanced Symptom Recognition • Advanced Error Recovery	*Maintenance Tasks for All Maintenance Engineers* • Preventive Maintenance • Basic Repair	Complex tasks that are frequent, but non-routine, and require judgment and applied expertise.
1	Ability to perform tool operations.	*Basic Tasks:* • Basic Operations • Simple Preventive Maintenance • Simple Error Recovery • Basic Symptom Recognition	*Operator Tasks*	Basic tasks that are required to operate the tool/equipment. Tasks that are fixed, routine, & non-judgmental.

Company 2 (above) *also* uses a detailed matrix scheme with [selected] examples for differing jobs. So there are examples specified for the operator, maintenance engineer, process engineer, and CSE — *at each level!* However, every performer must complete all tasks on Level 1 (for all of the job categories) before moving up to Levels 2 and 3 which are more specialized according to job.

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