Annual Report for Assessment of Outcomes 2012-13

Subject Area Committee Name: Microelectronics Technology
Contact person: Shelton Fu
For LDC/DE: Core outcome(s) assessed: _______________
For CTE: Degree or certificate* assessed: MT AAS
*please attach a table showing the alignment of the degree or certificate outcomes with the College Core Outcomes

Please address the questions below and
send to *learningassessment@pcc.edu* by **June 21, 2013** with Annual Report in the subject line

Note: Information provided in this report may be inserted into or summarized in Section 2C Program Review Outline.

MT AAS Program outcomes (outcomes reviewed this year are bolded, outcomes reviewed in the previous report are not bolded):

1. **Use systematic methodologies and apply understanding of process equipment to trouble-shoot common process equipment problems.**
2. **Apply a good foundation in maintenance to perform basic industry standard maintenance procedures.**
3. **Trouble-shoot basic analog and digital circuits.**
4. Monitor and maintain manufacturing processes.
5. **Work effectively in teams.**
6. Communicate effectively with colleagues and vendors

1. Describe changes that have been implemented towards improving students' attainment of outcomes that resulted from recent outcome assessments. These may include but are not limited to changes to content, materials, instruction, pedagogy etc. Please be sure to **describe the connection** between the assessment results and the changes made.

1.1 Changes Implemented--Troubleshoot equipment:

In past assessments, we noticed that even though the failure rate of our students in the assessment test had been reasonable, roughly 1/3 of our students passed the test marginally. This was a concern. This year, we adopted the following strategy to tackle this issue. We noticed that the practical exam score of an earlier course in the sequence correlates well with this assessment. We use this previous test score to flag the marginal performing students. We then alert the students themselves of their potential risk for failure. In the subsequent two courses leading to the assessment test, we keep on giving feedback about to them whether they are trajecting towards passing. This helps them to judge whether they need to commit more effort to change their trajectory.

We also assign our lab technician and student tutor to work with these students. We also split the lab groups with slower students into smaller sized groups so that the slower students will have more of a chance to practice trouble-shooting. We also explicitly ask their teammates to slow down to allow the slower students to have more chances to practice. Fortunately, all of our slower students this year showed a willingness to exert more effort. The instructor also needed to determine an individual student's strength and weakness early on. Fortunately, many of the students this year had certain redeeming qualities that enabled them to stage a comeback. Once discovered, the instructor should encourage the students to use their strength and improve upon their weakness to overcome the obstacles in their studies.

In the result section, one can see that this effort paid off. The % failure rate this year dropped significantly despite a large increase in our class size and thus less equipment availability for practice.

In 2011 assessment, we proposed the following two changes due to weakness seen in the isolation design area. "1. Go over the meta-thinking in trouble-shooting so that students can learn the methodology to trouble-shoot even unfamiliar problems." And 2. "Time permitting, always ask students to design the isolation tests first before instructor giving the answer in demo problems so that students develop the capability to solve problems on unfamiliar systems." We implemented both changes in the area of isolation test design. Student performance in the test design step in this year's assessment improved to an average score of above 90%.

1.2 Changes Implemented—Equipment Maintenance:

In the 2011 assessment report, we proposed that we should emphasize this year to students that while they practiced the maintenance procedure, the instructor was not with them to correct their mistakes. That is why they should have their teammates read the detailed instruction and requirement on this procedure step-by-step to judge and correct their mistakes while they practiced this procedure. We did implement this change this year.

1.3 Changes Implemented --Troubleshoot Circuit:

The 2011 assessment report emphasized weaknesses in troubleshooting in second year students, and recommended several changes to the second year process equipment sequence. Based on that analysis, the MT SAC decided to put forth efforts to further infuse troubleshooting concepts into the rest of the curriculum. As a result of this, a few changes in teaching the subject of electronics took place, more this academic year (2012-13) than ever before:

- The majority of the topics taught have now a new and stronger emphasis on troubleshooting. **For example** before, if the topic was "transistors", students were studying the type of, the characteristics of, and some applications of these devices, while the troubleshooting methodology of them was only occasionally touched. This year, a clear and consistent shift from the above mentioned content was implemented: for each type of transistor or transistor circuit, a table with "potential problem-possible cause-solution" is presented, and becomes the focus of the lecture about "transistors".
- Two new lab experiments were designed and implemented in MT 112, both with a strong emphasis in troubleshooting. In one of them, students have to test and recognize specific "faults" in transformers, and in the other they have to go through the same process of identifying "the problem-the cause-the solution"-all related to a solar-system-inverter circuit.
- Replacement of the on-paper-final-exam in MT 112 with a practical-in-lab final exam. The new practical final exam is dedicated mainly to circuit troubleshooting skill assessment.

1.4 Changes Implemented —Semiconductor Process: (not due this year)

The 2012 assessment indicated students were achieving this outcome and no changes were recommended. It was recommended that the evaluation tool be reevaluated – this is ongoing.

1.6 Changes Implemented —Communication: (not due this year)

The 2012 report indicated the department should evaluate how report organization and data presentation are integrated into classes, and to consider requiring COMM111 Public Speaking. A new course was developed on statistics for process control, which emphasizes handling and presentation of data. The report template utilized by the department was reevaluated and circulated among the teaching faculty. No action has been taken on COMM111.

For each outcome assessed this year:

2. Describe the assessment design (tool and processes) used. Include relevant information about:
   - The nature of the assessment (e.g., written work, project, portfolio, exam, survey, performance etc.) and if it is direct (assesses evidence mastery of outcomes) or indirect (student's perception of mastery). Please give rationale for indirect assessments (direct assessments are preferable).
   - The student sample assessed (including sample size relative to the targeted student population for the assessment activity) process and rationale for selection of the student sample. Why was this group of students and/or courses chosen?
   - Any rubrics, checklists, surveys or other tools that were used to evaluate the student work. (Please include with your report – OK to include in appendix). Where appropriate, identify benchmarks.
   - How you analyzed results, including steps taken to ensure that results are reliable (consistent from one evaluator to another.

2.1 Assessment design--Troubleshoot equipment:

Equipment trouble-shooting assessment takes the form of on-demand task performance. Instructors intentionally set up an error on our equipment and ask a student to isolate, identify, and fix the problem following a systematic trouble-shooting methodology. We test every student at the end of the MT228 course, which is a required course for graduation. Students typically take this class in their last term before graduation.

We use the following rubric to evaluate student performance. The current version of the rubric only differentiates between two levels of performance: proficient and non-proficient. Proficiency criteria:

a) Can demonstrate a consistent pattern of being able to systematically isolate the problem. And with non-substantial help, can solve an intermediate problem. Or,
b) Can demonstrate a consistent pattern of being able to systematically isolate the problem. And with some substantial help, but not in majority of the time, can solve a difficult problem.

See Appendix 1 for the definitions of systematic isolation methodology, consistent pattern, non-substantial help, and difficulty level of problems.

In addition to the above rubric, we also use three quantitative scores for analysis of the test results, Step Score, Performance Score, and Performance Index. See Appendix 2 for description of these parameters.

Reliability: Because our department is small, currently only one instructor is teaching the course in which this test is administrated, so inter-rater reliability is not an issue. If another instructor is to administrate the test, we will follow the training process below. The trainee will read the scoring guide document including three grading examples. After that, the trainer will describe three trouble-shooting processes undergone by previous year students with their written reports and ask the trainee to grade the processes. If the trainer and the trainee arrive at the same conclusion about students' performances in all clear cut cases and have reasonable agreement on marginal cases, then the trainee is cleared to grade student assessment tests independently from there on.

2.2 Assessment design--Equipment Maintenance:

We use on-demand performance of a maintenance procedure-- upper electrode replacement to assess equipment maintenance skills of students. The procedure is a major part of a basic industry standard maintenance procedure (a wet clean). An instructor observes individual student performing a representative part of this procedure (about 1/5 of the whole procedure), then grade him against the following rubric.

We test every student at the end of the MT228 course, which is a required course for graduation. Students typically take this class in their last term before graduation.

Score	Level	Grading Rubric		
		Style and Form	Speed and Familiarity	Quality
90	Good	Minor imperfection	& fluent, no hesitation	& No issue
80	Pass	Substantial imperfections	Or some hesitations	Or Minor issues but no damage
60	Fail	N/A	Can not complete the procedure without major help from the written procedure	Or Damage

Damages to equipment or process examples: scratching the electrode, forget to mount a screw, torque out of spec (even with the help of a written procedure), missed torquing a screw, baffle plates in the wrong order, damaging the ceramic parts, did not align the 3 holes of the lower clamp ring right, etc.

Minor quality issues: potential to create some particles, scratching the baffle plates, O-ring mounting not smooth, did not wipe the o-ring correctly, did not inspect the o-ring for cracks,

Speed issues: dropped a screw into the lower electrode well, missed a step but recovered later on, etc.

Our department is small. This course is currently always taught be a specific instructor, thus inter-rater reliability issue does not exist.

2.3 Assessment design--Troubleshoot circuits:

The assessment:

The practical exam taken at the end of the spring term in MT 113 class-Electric Circuit and Devices III was used for circuit troubleshooting assessment this year. The course is the last one the MT students would take in a series of five electronics courses. This is a direct assessment administered in the lab, the test is timed to one hour, and students are allowed to use their lab note book as a reference while taking the exam. The maximum score that could be earned is 5, which is 5% of the final grade for the course.

The examination includes 5 steps, each one having a "weight" of 1 point. If before 2013 some of the steps of the test were assessing different technical skills, now all 5 steps are dedicated to "circuit troubleshooting".

The sample:

Of all the students enrolled in MT 113 class (two sections) during spring term, 33 took the practical exam. This number represents the vast majority (98%) of the students finishing the first year in the program and at thus the entire sequence of MT electronics courses; this is the rational for choosing the timing of the assessment to be the end of the spring term.

The rubric:

The grading system for the test is very straightforward: each step is graded one at a time, on a "done or not done" basis, two tries per step. If at the first evaluation of the step the task was not properly performed, the students is give a second chance for only half of the credit (0.5points).

The analysis:

All the students were tested by the same instructor, and that eliminated the issue of lack of consistency in grading and assessing.

2.5 Assessment design--Teamwork

The assessment:

Currently the MT department includes no specific training or assessment of teamwork. We rely on the stated outcomes of specific LDE courses required for the degrees:

- WR227 Technical/Professional Writing: Work and problem solve effectively with others to achieve a common communication goal, using collaborative techniques, respecting the work of colleagues, and meeting deadlines; listen and speak reflectively.
- COMM215 Small Group Communication: Process and Theory
    1. Continue to adjust communicative behavior in order to improve the quality of small group interactions within various settings
    2. Manage projects, presentations, and small groups through learned communication strategies.
    3. Manage conflict through learned communication strategies within the small group setting.
    4. Use learned active listening skills in order to analyze and explain others' communicative behaviors within the small group

The sample:

All of the students completing the MT program this spring/summer (31 students).

The rubric:

Contact the writing and communications SACs

The analysis:

We use the reported grades as evidence that MT students are meeting the outcome of Teamwork. We rely on the associated departments to report reliable and meaningful grades reflecting their courses' stated outcomes.

3. Provide information about the results (i.e., what did you learn about how well students are meeting the outcomes)?
   - If scored (e.g., if a rubric or other scaled tool is used), please report the data, and relate to any appropriate benchmarks.
   - Results should be broken down in a way that is meaningful and useful for making improvements to teaching/learning. Please show those specific results.

3.1 Result--Troubleshoot equipment

A note on the special circumstance of this year's assessment: due to a large increase in class size, and limited equipment availability, students were forced to have larger groups in labs and in homework assignments. In previous years, we had mostly 3 students/equipment. This year, it was 4 students/equipment. Previous year assessments showed that roughly 1/3 of our students either marginally passed the assessment test or failed. Being a very hands-on equipment centered training program, we had reasons to be concerned that the poor availability of equipment would endanger the chance of the already marginal students of passing the assessment.

Proficiency:

	2013	2012	2011
Total # of students tested	31	26	15
Total # of students failed	2	3	3
% of failure	6.4	11.5	20
# of (marginal pass + failure)	7	7	4
% of (marginal pass + failure)	23	39	27

Marginal pass: students who passed with a thin margin. If the rules had been tighten slightly or interpreted more stringently, they might have failed.

Average Step Score (Break down of Performance Score by Steps of the Systematic Trouble-shooting Process)

1st round isolation					
Block Diagram	Possible Cause List	Test Design	Implementation of test	Interpretation of test result	1st Rd total
95	97	94	94	97	95

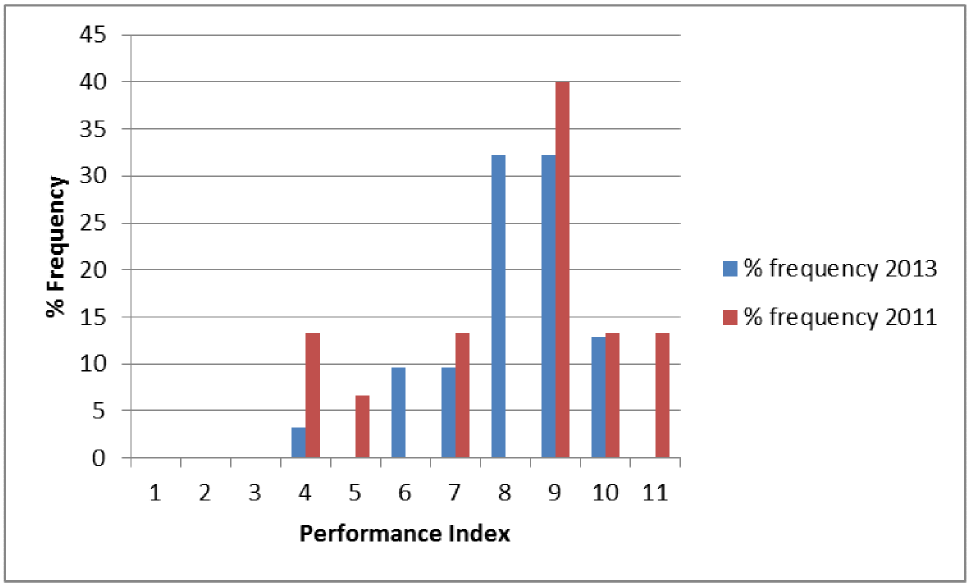
2nd round isolation					
Block Diagram	Possible Cause List	Test Design	Implementation of test	Interpretation of test result	2nd Rd total
95	97	90	82	80	88

Systematic isolation of the problem	Problem identified	Problem Fixed	Performance Score
92	97	73	90

(Test implementation and interpretation scores are usually lower because if a student cannot design a test, he will automatically lose part of the score in implementation and interpretation corresponding to that test)

Also, many of the tasks that used to be difficult for B level students can be routinely handled by C level students now, especially in the area of schematic reading, isolation test design, and He leak check. In addition, isolation test design used to be our weakest step, now student performance in that area improved. The next weakest step to address is test result interpretation.

Performance Index: The following chart shows the histogram comparison of the % of students in each year achieving each performance index level between 2013 and 2011.



Overall, student performance is very impressive. This is especially true in view of the large reduction of equipment availability discussed above. Not only the feared massive failure rate of marginal students did not occur, the percentage failure rate this year has dropped significantly. This is an unqualified success. On the other hand, the still large percentage of marginal passes remains a concern.

The overall improvement can be partially attributed to continued improvement in the trouble-shooting curriculum over the years. One can see a clear trend of the reduction of % failure rates over the last three years. This is also supported by a more granular analysis of the results – the average student performance across most of the steps of the systematic trouble-shooting process (step score) improved to 90% or above. 50% of our trouble-shooting curriculum was developed in the last 4 years. Over time, teaching contents have been developed to make the concepts much more clearly presented and better taught. For example, student went through one more round of schematic reading. Fewer students failed this year due to inability to read schematics. Another example is that the instructor this year spent much more time in demonstrating the common approaches to isolation test design. More students are able to design isolation tests, which used to be the weakest step in their trouble-shooting process. A third example is that now all students are required to go through at the least one round of Helium leak check in their homework assignment. Very few students had problems with carrying out the He check procedure this year. One can see the effect of this improvement in the assessment results. On the other hand, as the course matures, the pace of this improvement is expected to diminish soon.

We can see that the overall distribution of performance index is similar between 2013 and 2011. There may be a difference at the higher end and the lower end. At the higher end, 2013 students did not perform as well. At the lower end, however, 2013 students performed better. This year, the instructor did not give out as many challenging tasks at the higher end. Thus the more advanced students did not have a chance to earn a higher performance index score because the difficulty level of their tasks was not as high as they could have handled. This can explain some of the loss in the higher end of the performance index histogram.

While student performance in the assessment continues to improve, one should exercise caution on how much the general trouble-shooting skills of student improved. Most of the improvement is a result of clearer presentation of teaching materials. When the instructor lays out/spell out the steps of trouble-shooting our specific equipment more clearly, there are potentially two effects on the trouble-shooting skill of students. Firstly, the ability of students trouble-shooting our specific equipment improves. Secondly, the general skill of our students trouble-shooting all equipment improves. The more familiar students are with our specific equipment, the less independent judgment students need to solve problems on our equipment. This success can in part be translated to the solving of problems on other systems unfamiliar to our students, in so far as our equipment serves as an arch-type of other equipment. For example, vacuum trouble-shooting can follow certain scripts, if students can do well on our equipment, they can do well on others. Wafer transfer/robotic systems, on the other hand, can have much more variation from equipment to equipment. Instead of following a script, students have to exercise independent judgment at multiple points of their trouble-shooting process. If most of our improvement so far comes from students knowing the script better, the dividend of this kind of improvement is limited.

This year's assessment uncovered a problem in student performance at the Block Diagram step. In their 1st try of block diagram design, many students experienced problems, such as missing blocks, having blocks that are not mutually exclusive of each other, having blocks that are not aligned with isolation test designs. As such these students are not so conscious of the link between the divisions of blocks and the ultimate goal of problem isolation. Part of the cause of this problem is that the approach to systematic design of block diagrams is not addressed sufficiently in class. Instructor jumped too quickly into the standard block diagrams for each system, without explaining when to use which one.

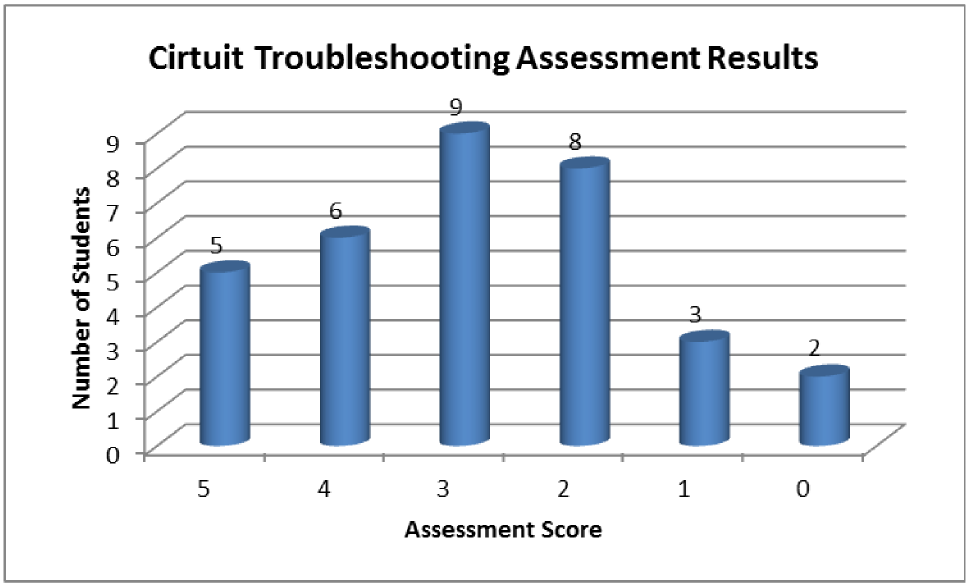
3.2 Result-- Equipment Maintenance:

	2013 Result		2011 Result	
Category	% in each category	# of students in each category	% in each category	# of students in each category
Good	68	21	67	10
Pass	19	6	20	3
Fail	13	4	13	2
Total	100	31	100	15

This result is shown in the table above. 2011 result is shown for comparison. There is no change from 2011. The failure rate of students is low 13%. And the % of students in the top category is high ~ 2/3 of the class.

3.3 Result -- Troubleshoot circuits:

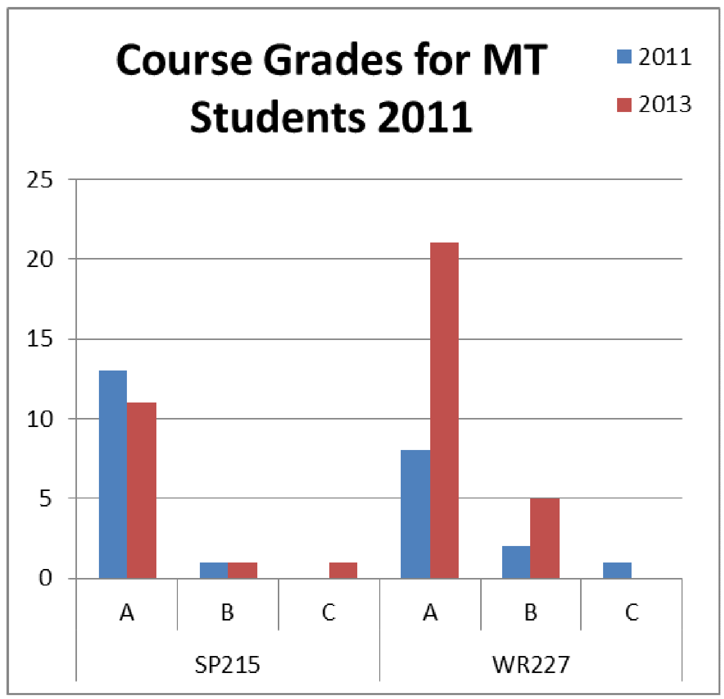
On a scale from 5 to 0, this is the distribution of the scores obtained by the 33 students that took the test at the end of spring term 2013. The average is 2.87



Considering 2.5 to be the cutoff score between "meeting" and "not meeting" the outcome, it is obvious that the average is barely larger; 20 students out of 33 have met the outcome (60%), while 13 did not (40%).

3.5 Result --Teamwork

The figure at right shows the course grades earned by currently graduating MT students along with the grades from the previous assessment report. It is expected that a student earning an A would have exhibited well all of the outcomes of the courses as defined in the CCOGs. This data shows that 82% of MT students are earning A's in these courses, so it is expected that most MT graduates are meeting the outcome for working in teams.



4. Identify any changes that should, as a result of this assessment, be implemented to help improve students' attainment of outcomes. (These may include, but are not limited to, changes in curriculum, content, materials, instruction, pedagogy etc).

4.1 Future Changes--Troubleshoot equipment:

To address the problem seen in block diagram design, instructor needs to spend more time discussing the approach to the design of block diagrams. Instructor may want to show how certain ways of division of a system may facilitate the design of isolation tests in later steps, whereas certain other ways do not. Instructor should also give examples of past student failures to illustrate this point. Instructor should also design written homework problems that illustrate problematic non-systematic block diagram designs, such as designs that have missing blocks, or have blocks that are not mutually exclusive of each other.

To improve in the area of test interpretation, we can design additional written homework problems for students to practice test interpretation in these specific areas that students had problems in previous tests: 1) Vacuum ROR interpretation after plexiglass capping of lower process chamber; 2) interpretation of leak size data from multiple adjacent locations to discern the actual location of the leak with previous student failure examples; 3) a homework assignment to explicitly interpret photo transistor probing result.

4.2 Future Changes--Equipment maintenance:

We may consider adding more notes to the written procedure to outline where previous students failed, and where in general students can easily make mistakes.

4.3 Future Changes--Troubleshoot circuits:

Redesigning the majority of the lab experiments in the series of electronics courses (MT 111+MT 112+MT 113) such that the consistent emphasis is circuit troubleshooting.

4.5 Future Changes--Teamwork

The results indicate no changes are required. It is not anticipated that the MT program will make any changes to the MT courses or program regarding the Teamwork outcome. To do so would require significant professional development and course development. Since the Writing and Communications departments already teach to this outcome, and have the expertise, work on this among the MT faculty would be a poor utilization of resources. It is expected that the Writing and Communications departments are evaluating their own courses regarding meeting their stated outcomes.

5. Reflect on the effectiveness of this assessment tool and assessment process. Please describe any changes to assessment methodology that would lead to more meaningful results if this assessment were to be repeated (or adapted to another outcome). Is there a different kind of assessment tool or process that the SAC would like to use for this outcome in the future? If the assessment tool and processes does not need to be revised, please indicate this.

5.1 Assessment Effectiveness-- Troubleshoot equipment:

Our assessment tool can assess how well student will do in their future jobs in the equipment trouble-shooting area because the trouble-shooting tasks that we set up are very realistic. One can also see from the evidences reported above, it also effectively reflects changes in student performance. Detailed analysis of its results can also offer powerful diagnosis of issues in the teaching and the learning of this learning outcome. The major disadvantage of this tool is that it is very time consuming. Each day, only 3 students can be tested due to limited equipment availability. (Don't even think about it. Original MSRP of each piece of equipment is $1.5Million) It takes a student 4 ~ 10 hours to solve a problem. (Bring your own lunch, bath room breaks allowed, smoking run for addicts? – no chance) When it was first conceived, we had around 15 graduates per year. Now we have around 30. (And you ask why this report is late? We were still giving out exams the week after the final week was over.) Seriously, can we postpone the assessment report deadline to the end of summer so that instructors can have more time to analyze the results?

One main time consuming part of the test is in the writing of the report by students to document their systematic trouble-shooting steps. Currently, after a student writes down their block diagram design, list of possible causes, and isolation test design, the instructor reads the report and then gives them feedback. If the designs are deemed to be insufficiently systematic, students have to re-develop their design and rewrite the report. This back-and-forth can take a couple of hours. One way to save time is for the instructor to have a preview of the report after the 1st step -- block diagram design. If non-systematic approach is already evident, the instructor can give an early feedback to the student, so that the student will not need to waste time pursuing a wrong direction further.

Another aspect of the assessment we can improve upon is to develop more errors that can probe into the ability of our student to trouble-shoot unfamiliar systems, which force them to display their ability to adapt what they are taught to new situations. There are parts of the equipment that we do not currently cover in lectures. We can test students on errors in those parts. This is a multi-year project to develop such errors.

5.2 Assessment Effectiveness-- Equipment Maintenance

This method has been very effective. And it is how a trainer would judge whether a trainee is proficient in the performance of a maintenance procedure in the industry. No need of revision currently.

5.3 Assessment Effectiveness-- Troubleshoot circuits

In order to increase the accuracy of the assessment, future changes may include using more than on "measurement point": in addition to the test described above and used for assessing the "circuit troubleshooting" outcome, the SAC may consider using the scores on the practical exams given in MT 112 and MT 111, the first two electronic courses of the entire sequence.

5.5 Assessment Effectiveness -- Teamwork

The assessment methods used here are minimally invasive as they utilize assessments already integrated into the curriculum. Their effectiveness is wholly dependent on the Writing and Communications faculty in reporting grades based on course outcomes. This best utilizes available resources. No change is expected at this point.

Appendix 1: Definitions of terms used in Proficiency Criterion of Equipment Trouble-shooting Skills Assessment:

Systematic isolation methodology: The student has to be able to isolate the problem from a whole complex system to smaller and smaller blocks. Example, the gas delivery example shows well what it means to isolate the problem to ever smaller blocks. Instructor has to steer the student back to systematic isolation steps. Systematic approach to isolation: isolation has to be done using a systematic approach, guesses no matter how good do not qualify as systematic isolation. The systematic isolation steps outline above is an example of a systematic approach. Currently, students are presented these steps in a handout at the beginning of the test. They are required to follow these exact steps at least in the first few rounds of isolation until the instructor is satisfied that the student has demonstrated a consistent pattern of being able to apply this systematic approach. Example, if a student can guess intuitively the nature of the problem based on observations of clues, and directly identifies the problem, it does not quality for systematic isolation.

Steps of systematic isolation methodology:

Step 1: Perform a prescribed task on the etcher during which the student will discover an error. At this point the student will be asked to write down a problem statement.

Step2: Draw a block diagram of the whole system involved in the problem, including all the component blocks involved and their relations. Identify all possible culprit blocks and describe how they can produce the problem.

Step3: Design an isolation test for each block to see if that block is responsible for the problem. The test needs to be as much as possible definitive, comprehensive, and easy to implement. When writing out the tests in the following format:

Test description	Possible outcome	Conclusion

Step4: Prioritize the order of the tests based on the balance between how likely the cause is and how easy it is to implement the test.

Step 5: Implement the tests

Step6: Correctly interpret the test results and draw conclusion as to which one of the blocks is the culprit.

After the first two rounds of isolation, more rounds of isolation may be needed. However, students are no longer required to write down the steps. But the instructor can still choose to follow and grade the student in the isolation process.

The following table is a summary of the systematic isolation steps above:

<table>
<tr><td rowspan="5">Systematic Isolation of the Problem</td><td colspan="2">Steps and Description</td></tr>
<tr><td colspan="2">Break a complex system down to simpler blocks</td></tr>
<tr><td colspan="2">Identify all possible causes of the problem among the blocks. (Hypothesis)</td></tr>
<tr><td rowspan="2">Hypothesis</td><td>Design of test</td></tr>
<tr><td>Priority of test</td></tr>
</table>

<table>
<tr><td rowspan="3"></td><td rowspan="2"></td><td>Performance of test</td></tr>
<tr><td>Interpretation of test results</td></tr>
<tr><td colspan="2">Iteration of the above steps to isolate the problem further</td></tr>
</table>

Consistent pattern: has to be a consistent pattern but not 100%. For example, if a problems requires 3 rounds of isolation, and one round turns out to be of an advanced level, if a student successfully completed the two intermediate level isolations, but had problem doing the advanced round, he is still deemed to have demonstrated a pattern of successful isolation. Another example, for isolation test designs. Many times there are several blocks in a system. If a student is able to design tests for most of them, but made mistakes in design tests for a few of them, even major mistakes, the student is deemed to have demonstrated a pattern of successful isolation test designs.

Gauging step/parts definition: of the steps required in systematic trouble-shooting above, these are the gauging steps upon which student proficiency level will be judged: breaking a system into blocks, identification of possible causes, design of isolation test, interpretation of test results. Other steps, including the data collection part are non-gauging.

Non-substantial help definition:

1) Any help in any of the non-gauging parts of the exam is not counted as substantial help. Example 1: help in defining the problem statement is not counted as substantial help. For example, if the ELL arm extension to load point was short. A student may not have noticed that. Then the arm would refuse to retract which caught the attention of the student. As a result, the student may think the problem is the failure to retract problem not the short extension problem, each with a somewhat different nature and possible cause. Instructor can shine some light on the real problem. It would not count as substantial help here. Example 2: In test implementation, if a student forgot to turn 24V actuator switch back before taking a sensor reading which requires 24V power on in implementing a test, and an instructor reminds the student of that, it is not counted as substantial help here. Example3, in test implementation, a student needs to shut of the main gas shut off valve. He thought it was called V2 instead of V5, an instructor corrects him, it is not counted as substantial.
2) After a student is able to demonstrate a consistent pattern of being able to perform a gauging task, if she makes a mistake in that area, and the instructor has to correct her, this help is not counted as substantial.
3) Help in interpretation of test that are factual in nature is not counted as substantial help (e.g. An instructor can provide a fact to a student which is needed to interpret a test result, such as "this sensor is active high, not low). Help in the logic of the test interpretation is substantial help.

Difficulty Level definition:

Intermediate level (two categories A+B):

Category A: Systems familiar to students (pneumatics, vacuum, gas delivery, entrance load lock arm, shuttle arm, load point lifter.)

1) Isolation tests: most if not all isolation test designs are known to students in a generic form. They may have to customize the design to their specific case.
2) Unlikely to identify it by chance or obvious clues
3) >= 2 rounds of isolation before getting to the culprit component.
4) No components in the system strongly interact with others (not an interactive problem). Not an intermittent problem.

Category B: Systems unfamiliar to students (pre-aligner, indexer, gap drive etc.)

1) Unlikely to identify it by chance or obvious clues
2) No restriction on minimal rounds of isolation
3) No components in the system strongly interact with others (not an interactive problem). Not an intermittent problem.

Difficult Level:

1) Not immediately obvious which system is responsible for the error: wafer transfer initialization error, multiple stations involved, Or
2) >= 3 rounds of isolation necessary to identify the culprit component, Or
3) Very complex system: many blocks at same level to eliminate from, Or
4) Isolation test is difficult to design, or
5) Unfamiliar system with medium complexity, or
6) Interactive problems, but
7) Not intermittent.

Appendix 2: Definitions of terms used in Proficiency Criterion of Equipment Trouble-shooting Skills Assessment:

Step Score, Performance Score, and Performance Index Description
Step Score (Break down of Performance Score by Steps of the Systematic Trouble-shooting Process): Other than the qualitative categories of proficiency (pass) and non-proficiency (fail), each student also receives a numeric grade of 0~100 on each of the steps in their systematic trouble-shooting process (e.g. Block diagram in 1st round of isolation, Test Result Interpretation in 2nd round of isolation, etc.). This is called the Step Scores.

Performance Score: The individual step scores are then summed up with a weighted scale to form one single numeric score to measure the performance of the student in the entire assessment test. This is called the Performance Score. In general, students scoring less than 60 fail the test (non-proficient).

Performance index: To be able to compare student performance across multiple years, we attempt to factor out certain year-to-year variations from the numeric score, variations that do not reflect the true improvement of the curriculum. The two such variations we considered are: the year-to-year variation of general competence of students incoming to this class; the year-to-year variation of the difficulty level of the trouble-shooting tasks assigned. A performance index is constructed to factor out these variations.

Performance index = Performance score * Problem difficulty level / student level. Student Level (0~100 scale) is a measure of general competence of students incoming to this class. (A level student = 95, B=85, D=65 etc.) Difficulty level of the trouble-shooting task is a 0~10 scale indicator with 10 being the most difficult problem. The student level is in the denominator to try to remove student general competency variation from year to year as a factor. So the higher the performance score, on more difficult problems, performed by lower competency students, will receive a higher index.