

PBL Challenge Implementation Guide

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Table of Contents

PBL Challenge Implementation Flow Diagram	3
Introduction to the PBL Challenges	4
PBL Challenge Site Map	.....	5
Implementation Instructions	.....	6
Structured Challenge	.....	6
Guided Challenge	.....	8
Open-ended Challenge	.....	9
Assessment	.....	10
Calculating Student Grades	.....	11
Challenge Page Descriptions	.....	12
Appendix	.....	17
Challenge Passwords	.....	18
White Boards	.....	20
PBL Final Challenge Report	.....	26
PBL Final Challenge Report Scoring Rubric	.....	27
Concept Mapping Instructions	.....	29
Concept Mapping Scoring Rubric	.....	33

PHOTON PBL Challenge Implementation Flow Chart

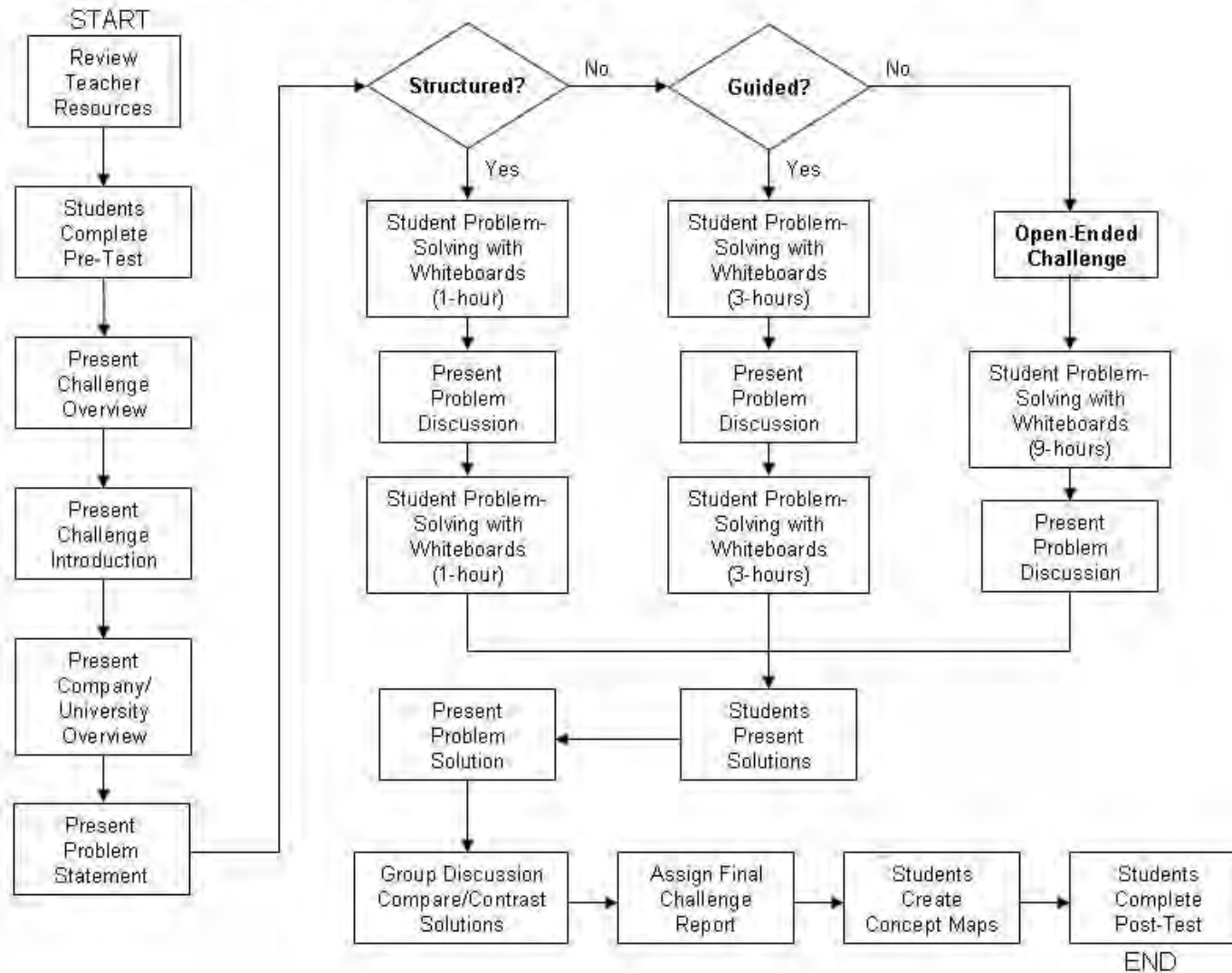


Figure 1 – PBL Implementation Flow Chart

PBL Challenge Implementation Guide

I. Introduction to the PBL Challenges

The PBL challenges are located at the following website:

<http://pblprojects.org>

PBL Challenge Main Pages

Each PBL Challenge contains six main pages:

- 1) Challenge Overview
- 2) Introduction
- 3) Company/University Overview
- 4) Problem Statement
- 5) Problem Discussion
- 6) Problem Solution

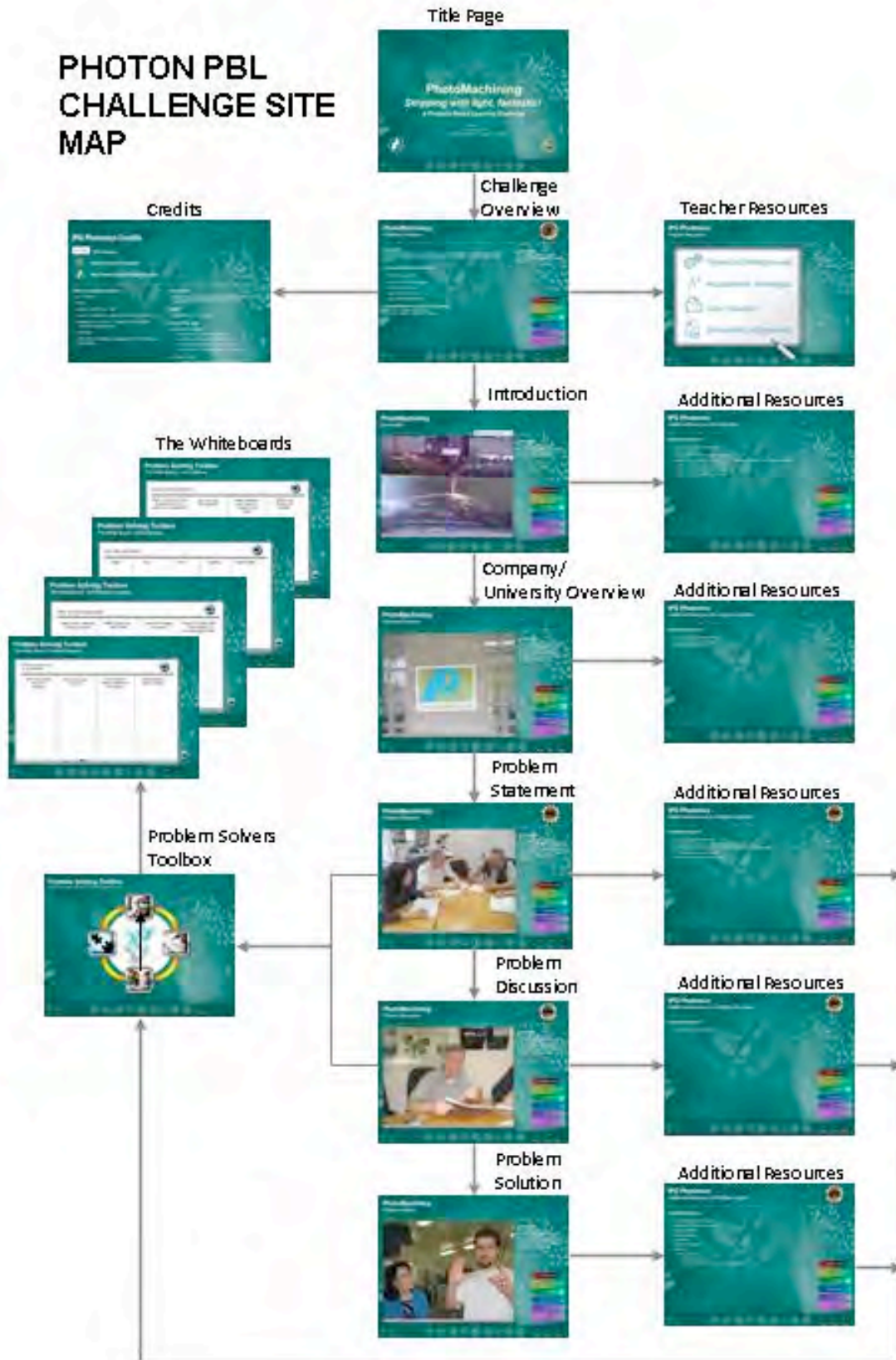
Table 1 provides a description of each PBL Challenge page. The PBL Challenge site map is shown in Figure 2. * ***Challenge passwords located in the Appendix.***

PBL Challenge Resource Pages

Each PBL Challenge contains instructional resources for teachers (**Teacher Resources**) and a problem solving resource (**Problem-Solver's Toolbox**) for students. Table 2 provides a description of the Problem Solving Toolbox.

- 1) **Teacher Resources:** *Password-protected link on Challenge Overview page*
 - a. **Technical Background** – A comprehensive tutorial to prepare teachers for the technical content presented in the Challenge. Contains a detailed description of the problem situation and solution.
 - b. **Assessment Strategies** – A three-pronged assessment tool that includes a question bank with solutions. A concept mapping exercise with instructions, and a problem solving assessment tool. Scoring rubrics are included.
 - c. **Implementation Stories** – A collection of case studies describing how other teachers have implemented the Challenge in a number of different settings and grade levels.
 - d. **Standards Alignment** – Alignment to national science and technology literacy standards.
- 2) **Problem Solver's Toolbox:** *Link on Problem Statement and Problem Discussion pages*
 - a. **The Whiteboards** - A tool for developing student problem solving skills
 - b. **Additional Resources** – Valuable additional information located on each Challenge slide

PHOTON PBL CHALLENGE SITE MAP



II. Implementation Instructions

The PBL Challenges employ a three-level scaffolded design to “ease” students into the PBL instructional method. The three levels range from **Structured** (Instructor Led), to **Guided** (Instructor Guided), to **Open-Ended** (Instructor as Consultant) depending on the technical nature of the problem and the ability level of the students. Each of the PBL Challenges contains **password-protected** sections to allow instructors control of the format (Structured, Guided or Open-Ended) and pace of instruction (see attached for PBL Challenge passwords). In general, students who are new to the PBL challenges should begin using the structured approach, then progress to the guided approach, and finally the open-ended approach once they are comfortable with the PBL process

Prior to introducing the PBL Challenge, instructors should review the technical overview located in the password-protected **Teacher Resources** section of the challenge to become acquainted with the problem situation, the technical principles reinforced, and the problem solution.

While institutions may differ in how course time is scheduled, the following implementation recommendations are based on a 3-hr lecture/3-hr lab per week course format in which the PBL Challenge is presented as a supplemental laboratory activity.

A. **Structured Challenge (Instructor Led):**

Estimated Time for Completion: *One 3-hour lab class + 1-3 hour follow-up*

Used for students with no PBL experience and/or limited technical background. This approach is essentially an interactive multimedia case study. A structured challenge can be introduced in one 3-hour lab period with follow up review during the next class. Prior to the class in which the Challenge will be introduced, assign homework problems from the question bank located in the **Teacher Resources** section as a pre-assessment.

STEPS:

Class 1

1. Present **Challenge Overview** and review additional resources with students
2. Present **Introduction** video and review additional resources with students
3. Present **Company/University Overview** video and review additional resources with students
4. Present **Problem Statement** video and review additional resources with students
5. Explain the **Problem Solvers Toolbox** and introduce the **Whiteboards**.
6. Break the class into small teams of 3-4 students and instruct the students to complete each of the four Whiteboards to the best of their ability. Students should follow the following steps:

- a. Complete the **Problem Analysis Whiteboard** to frame the problem
 - b. Complete the **Independent Research Whiteboard** to acquire any additional information needed
 - c. Complete the **Brainstorming Whiteboard** to develop a possible solution
 - d. Complete the **Test Your Idea Whiteboard** to develop an initial plan for testing the viability of their solution
7. Allow approximately 1-hour for students to complete their first iteration of the four Whiteboards.

NOTE: There will NOT be enough information to solve the problem at this time. Reassure students that this is the nature of real-world problems and what they are learning is a systematic process that they can apply in solving any problem.

8. Reconvene class and present the **Problem Discussion**. Provide students with the Problem Discussion password (PD #####) so that they can seek out additional information. Break students into their teams again and continue group problem solving session using the Whiteboards and have students fill in any missing information. Provide students with additional time to continue working towards their solutions (Approximately 1-hour). Near the end of this session, have students prepare a simple PowerPoint presentation in which they outline their problem solving process and solution. Have them use the Whiteboards as a guide.
9. **Student Presentations:** Have students present their solutions in an informal presentation and describe the process (referring to the Whiteboards) they used to solve the problem (Approximately 30 minutes).
10. Present the **Problem Solution** video to the class and provide them with Problem Solution password (PS #####) so that they can review the solution on their own. Conduct a group discussion to compare and contrast solutions (Approximately 30 minutes).
11. Assign students the **Final Challenge Report** to be completed as a homework assignment. Provide them with the **Final Challenge Report Scoring Rubric** to guide their report preparation.

Class II

12. Break students into small groups (3-4 students) and guide them in creating a Concept Map for the Challenge (concept mapping instructions provided in **Teacher Resource** section; allow approximately 1-3 hours in class or assign for homework). Provide students with Concept Map Scoring Rubric to guide their work.

13. Assign homework problems from the question bank located in the **Teacher Resources** section as a post-assessment.

B. Guided Challenge (Instructor Guided):

Estimated Time for Completion: Two 3-hour classes + 1-3 hour follow-up)

Once introduced to the PBL process using the structured approach, students can progress to the guided approach. The guided approach is similar to structured approach, but student groups are allowed to work with limited instructor supervision and are provided more time to develop a more complete solution. The instructor acts as a facilitator to ensure that students stay on track, but refrains from providing solutions or answers to specific questions. This strategy is intended to further develop students' ability to think critically by allowing them to actively engage in the problem-solving process, but at the same time providing a safety net so that learning occurs without risk of failure. Prior to the class in which the Challenge will be introduced, assign homework problems from the question bank located in the **Teacher Resources** section as a pre-assessment.

STEPS:

Class 1

1. Repeat **Structured Challenge Steps 1-6**. Have students complete the Whiteboards as done previously. Reiterate that it is **extremely important** to be as thorough as possible when completing the Whiteboards. Allow a complete 3-hour class session for this activity and encourage students to continue their work outside of class.

Class II

2. Present **Problem Discussion** to the class and provide students with the Problem Discussion password (PD #####). Reconvene student teams and allow students the remainder of the class period to continue working on their problem solutions. Continue to provide guidance as needed, but limit your input to guiding questions instead of simply providing answers. At this point students should be well on their way to converging on their problem solution and test plan, and should begin putting together their PowerPoint solution presentation.

Class III

3. **Student Presentations:** Have students present their solutions in a formal PPT presentation. As in the structured approach, students should describe the process (referring to the Whiteboards) they used to solve the problem (Approximately 30 minutes).
4. Repeat **Structured Approach Steps 10-13**.

C. Open-Ended Challenge (Instructor as Consultant):

Estimated Time for Completion: *Three 3-hour classes + 1-3 hour follow-up*

In the open-ended approach, students are presented with the most realistic representation of the problem as it would be encountered in the real world. In the open-ended approach, students are provided only with information from the **Introduction, Company/University Overview, and Problem Statement**, and are tasked with researching and developing their own solutions without the benefit of the **Problem Discussion**. Drawing on the problem-solving skills developed through engagement in the structured and guided approaches, students complete the Whiteboards with minimal guidance. During this process, the instructor acts as a consultant, providing hints or clues on request, but for a price (e.g., points deducted from a mock budget). Only after the student solutions have been presented are the Problem Discussion and Problem Solution revealed. Student solutions are then compared and contrasted with the Challenge solution in a group discussion and recommendations for improvements are discussed.

STEPS:

Class 1

1. Repeat **Structured Challenge Steps 1-6**. Reiterate the **importance** of being as thorough as possible when completing the Whiteboards. Allow 2-3 complete class periods (3-6 hours) for students to work through the Whiteboards, conduct research, and develop their solutions and test plans. Instruct students to make sure they budget enough time for their work.

Classes II & III

2. Allow student teams to continue working on their solutions while providing guidance and feedback upon request. Continue to provide guidance as needed, but limit your input to guiding questions instead of simply providing answers. One option is to allow students a budget of only *three questions per team* to force them to focus on the truly important aspects of the problem.

Class IV

3. **Student Presentations:** Have students present their solutions in a formal PPT presentation. As in the structured approach and guided approach, students should describe in detail the process (referring to the Whiteboards) they used to solve the problem (Approximately 30 minutes).
4. Repeat **Structured Approach Steps 10-13**.

III. Assessment

The PBL Challenges include three student assessment measures: (1) Content knowledge, (2) conceptual knowledge, and (3) problem-solving ability. Instruction for each of these assessment measures are located in the **Teacher Resources** section of each Challenge and are password protected. A summary of each measure is as follows:

A. Content Knowledge

A question bank consisting of multiple choice questions pertaining to technical content associated with each challenge is available in the Teacher Resources section of each Challenge. We recommend that pre-post testing be conducted with each challenge introduced to provide a measure of improvement in content knowledge associated with each Challenge.

B. Conceptual Knowledge

Conceptual knowledge is assessed through concept mapping. Each Challenge contains a list of main concepts, a reference concept map (for instructors), detailed instructions for students on how to construct a concept map, and a concept map scoring rubric. We recommend that upon completion of the first structured Challenge, instructors introduce the process of concept mapping using a simple topic (included in the instructions) to ensure students understand the structure and process for creating a concept map and how they will be assessed (provide students with the scoring rubric). Once students are clear on how to construct a concept map and how they will be assessed, assign the concept map exercise for the particular Challenge, and allow students to work on it with their team and/or complete it for homework.

C. Problem Solving Ability

Problem solving ability is assessed using the Final Challenge Report, which requires students to summarize the problem solving process they engaged in to solve the problem. This reflective activity provides an assessment of the knowledge, skills, strategies, and teamwork employed in solving the challenge, and of the quality of the students' solution. We recommend that the Final Challenge Report be assigned *after* completion of the students' solution presentation, but *before* the concept mapping exercise. The assessment sequence is illustrated in Figure 3.



Figure 3 – Assessment Sequence

Calculating Student Grade

Total Score

Total score is calculated using a weighted sum of content knowledge (C), conceptual knowledge (K), problem solving ability (P), and teamwork (T):

$$\text{Total Score} = w_1 \cdot (C) + w_2 \cdot (K) + w_3 \cdot (P) + w_4 T$$

where w_1 , w_2 , w_3 and w_4 are weighting factors determined by the instructor. This is illustrated below in Figure 4. Detailed instructions and resources for assessing content knowledge, conceptual knowledge, and problem solving ability can be found in the **Teacher Resources** section of each Challenge under *Assessment Strategies*.

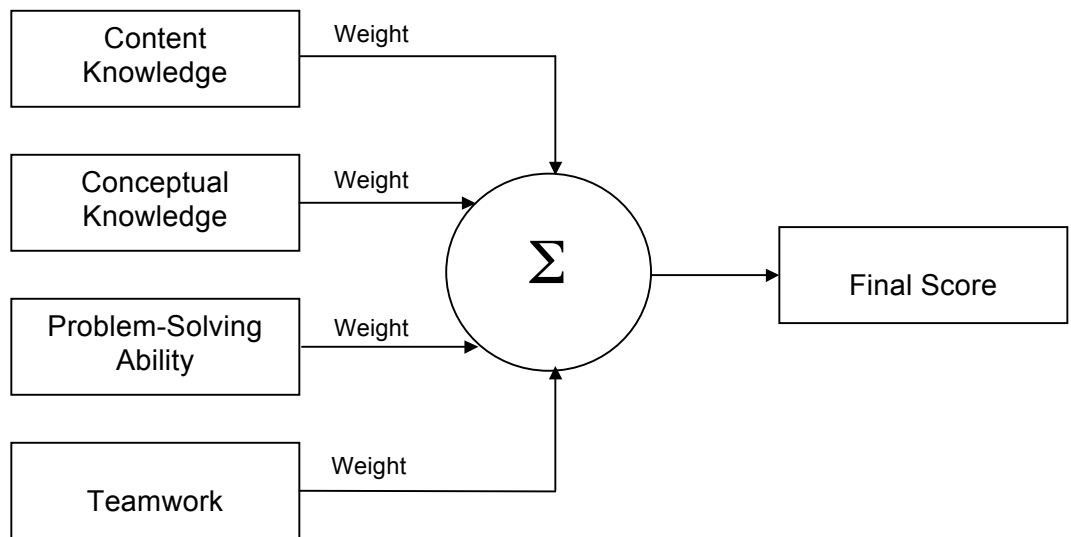


Figure 4 – Student Assessment in PBL

Table 1 - PBL Challenge Main Challenge Pages

<p>Challenge Page 1 PBL Challenge Front Page</p>	
<p>Challenge Page 2 PBL Challenge Overview This page provides a brief description of the challenge, the principles reinforced, a portal leading to the Teacher Resource page, and an array of buttons for accessing the different segments of the challenge which appear on each proceeding slide</p>	
<p>Challenge Page 3 PBL Challenge Introduction This page provides a multimedia introduction to the technology being addressed in the challenge.</p>	
<p>Challenge Page 4 Organization Overview This page provides a multimedia tour of sponsoring organization to provide the student with a brief overview of the context in which the problem was solved.</p>	

Table 1 - PBL Main Challenge Pages - Continued




<p style="text-align: center;">Challenge Page 5 Problem Statement</p> <p>This page provides a multimedia re-enactment of the problem as it was originally tour of the company or university lab to provide the student with a brief overview of the context in which the problem was solved.</p>	
<p style="text-align: center;">Challenge Page 6 Problem Discussion</p> <p>This password-protected page provides a multimedia re-enactment of the brainstorming session conducted by the technical personnel who originally solved the problem. The purpose is to provide students with “hints” as to how the original team approached to problem to help guide the students in their problem solving session. The password is provided by the instructor at a point in the challenge activity when students conclude that more information is needed to solve the problem.</p>	
<p style="text-align: center;">Challenge Page 7 Problem Solution</p> <p>This password-protected page provides a multimedia presentation of the actual problem solution developed by the company or university research lab. Each challenge contains detailed technical resources and tutorials that clearly explain the solution and provide thought-provoking questions designed to explore further key concepts and principles.</p>	

Table 2 - PBL Problem Solving Toolbox

<p>Problem Solving Toolbox Slide 1</p> <p>The Problem Solving Cycle</p> <p>The problem solving toolbox is designed to help students develop a systematic method for solving ill-structured problems. Problem solving is a recursive process involving four main steps: (1) Problem analysis, (2) Independent Research, (3) Brainstorming, and (4) Test Your Idea. Clicking on any of the four icons will bring you to the “Whiteboards.” The whiteboards can be projected onto an actual classroom whiteboard to help instructors facilitate the problem-solving process.</p>	 <p>Problem Solving Toolbox Click on the graphic to begin the problem solving process.</p> <p>SCIENCE TECHNOLOGY ENGINEERING MATH</p>								
<p>Problem Solving Toolbox Slide 2</p> <p>The Problem-Analysis Whiteboard</p> <p>The first step in problem solving is to clearly and accurately define the problem. This is what we mean by <i>problem analysis</i>. To get started on a problem solution, you must (1) clearly define the problem and the criteria for a successful solution, (2) identify what you know, (3) what you need to learn, and (4) identify any special constraints that apply or assumptions we must make. Only when you’ve clearly and accurately defined these parameters can you develop an effective plan for action.</p>	 <p>Problem Analysis Whiteboard</p> <table border="1"> <thead> <tr> <th>Clearly define the problem and list the criteria for a successful solution.</th> <th>What do we know about the problem?</th> <th>What do you need to learn?</th> <th>Are there any special constraints that apply or assumptions we must make?</th> </tr> </thead> <tbody> <tr> <td></td> <td></td> <td></td> <td></td> </tr> </tbody> </table> <p>SCIENCE TECHNOLOGY ENGINEERING MATH</p>	Clearly define the problem and list the criteria for a successful solution.	What do we know about the problem?	What do you need to learn?	Are there any special constraints that apply or assumptions we must make?				
Clearly define the problem and list the criteria for a successful solution.	What do we know about the problem?	What do you need to learn?	Are there any special constraints that apply or assumptions we must make?						
<p>Problem Solving Toolbox Slide 3</p> <p>The Independent Research Learning Whiteboard</p> <p><i>Independent Research</i> requires taking responsibility for acquiring the knowledge and skills identified in the problem analysis phase needed to solve the problem. This includes setting specific learning goals, dividing up the research tasks in a fair and effective manner, establishing timelines, and developing an effective strategy for acquiring the knowledge and skills needed to solve the problem.</p>	 <p>Independent Research Whiteboard</p> <table border="1"> <thead> <tr> <th>Specifically, what do we need to learn? (Make a list)</th> <th>How will we divide up the learning between team members? Who will do what?</th> <th>How much time do I have to complete my research?</th> <th>What is my strategy for acquiring the knowledge and skills needed to solve the problem?</th> </tr> </thead> <tbody> <tr> <td></td> <td></td> <td></td> <td></td> </tr> </tbody> </table> <p>SCIENCE TECHNOLOGY ENGINEERING MATH</p>	Specifically, what do we need to learn? (Make a list)	How will we divide up the learning between team members? Who will do what?	How much time do I have to complete my research?	What is my strategy for acquiring the knowledge and skills needed to solve the problem?				
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Table 2 - PBL Problem Solving Toolbox - Continued

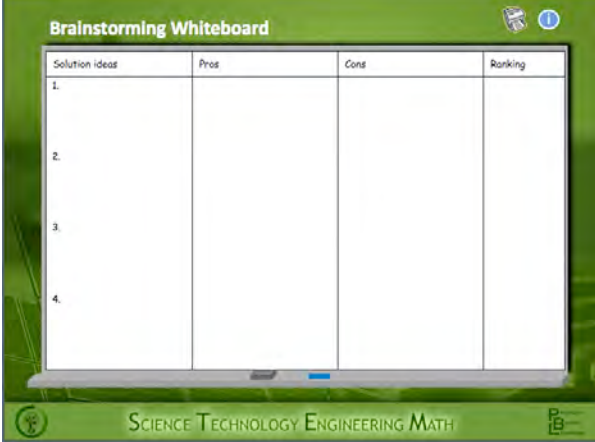
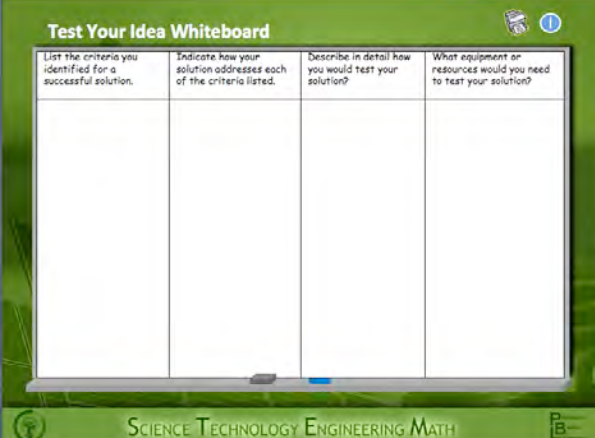
<p>Problem Solving Toolbox Slide 4</p> <p>The Brainstorming Whiteboard</p> <p><i>Brainstorming</i> involves applying what you’ve learned through your independent research in a group effort to generate possible solutions to the problem. By sharing your knowledge and ideas with others, you will be able to gauge your level understanding, integrate new information with your own prior knowledge, and converge on a solution that represents the collective knowledge of the group.</p>	
<p>Problem Solving Toolbox Slide 5</p> <p>The Testing Your Idea Whiteboard</p> <p>Testing your idea requires developing a viable test plan with specific performance criteria to validate your solution (i.e., How can you show that your solution actually solves the problem?). <i>One very important characteristic of a good test plan is that someone of reasonable intelligence can follow your plan and replicate your results.</i> If your test plan does not or cannot successfully validate your solution, the problem-solving process is repeated until an acceptable solution and test plan is developed.</p>	

Table 3 – PBL Teacher Resources


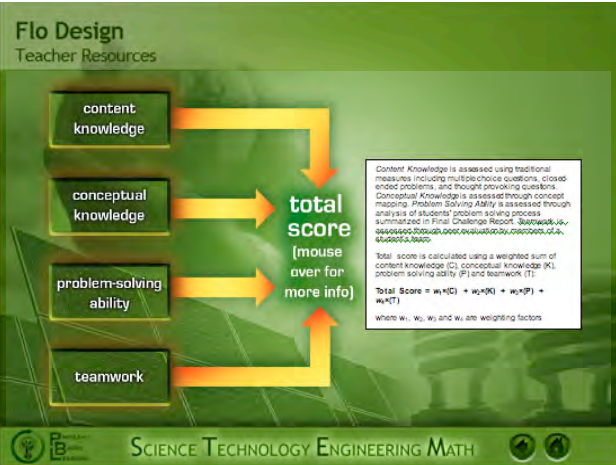
<p>Teacher Resources Page</p> <p>The Teacher Resource Page contains four links:</p> <ol style="list-style-type: none"> 1. Technical Background - A technical tutorial for teachers to provide background knowledge related to the challenge. 2. Assessment Strategies: A complete tutorial and instructions for assessing student content knowledge, conceptual knowledge, and problem solving ability. 3. Implementation Stories: Examples of different implementation strategies compiled from two years of field-testing in HS and college level classrooms. 4. Standards Alignment: PBL Challenges are aligned with National Science and Technological Literacy standards. 5. How-To-Video: Link to a five-minute video on using the Challenges in the classroom. 	
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Table 3 – PBL Teacher Resources - Continued

<p style="text-align: center;">Teacher Resources Page</p> <p style="text-align: center;">Assessment Strategies</p> <p>Student grades (Total Score) are calculated using a weighted sum of content knowledge, conceptual knowledge, problem solving ability and teamwork. Clicking on each button reveals assessment tools and scoring rubrics for content knowledge, conceptual mapping (concept maps), problem solving ability (Final Challenge Report) and a peer teamwork assessment.</p>	 <p>Flo Design Teacher Resources</p> <p>content knowledge</p> <p>conceptual knowledge</p> <p>problem-solving ability</p> <p>teamwork</p> <p>total score (mouse over for more info)</p> <p>Content Knowledge is assessed using traditional measures including multiple-choice questions, closed-ended problems, and thought-provoking questions. Conceptual Knowledge is assessed through concept mapping. Problem Solving Ability is assessed through analysis of students' problem-solving process summarized in Final Challenge Report. Knowledge, Problem Solving Ability, and Teamwork are assessed through peer evaluation by observers of a Final Challenge Report.</p> <p>Total score is calculated using a weighted sum of content knowledge (C), conceptual knowledge (K), problem solving ability (P) and teamwork (T).</p> $\text{Total Score} = w_1*CK + w_2*CK + w_3*PS + w_4*TT$ <p>where w_1, w_2, w_3, and w_4 are weighting factors.</p> <p>SCIENCE TECHNOLOGY ENGINEERING MATH</p>
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APPENDIX

- Challenge Passwords
- PBL “How-to” video
- The Whiteboards
- Final Challenge Report
- Final Challenge Report Scoring Rubric
- Concept Mapping Instructions
- Concept Map Scoping Rubric

PBL Challenge Passwords

PHOTON and STEM PBL passwords can be obtained from the Principal Investigator, Fenna Hanes, senior director of programs at the New England Board of Higher Education (NEBHE). Contact information is provided below:

Fenna Hanes

Email: fhanes@nebhe.org

Phone: 617-357-9620 x 129

PBL “How-To” Video

To learn more about how to implement problem-based learning Challenges in your classroom, please watch the multimedia “How-to” video located on the www.pblprojects.org website. A direct link to the video may be found here: <http://www.youtube.com/watch?v=9ppeGIKLOOE>.

The White Boards

I. Problem Analysis Whiteboard

The first step in problem solving is to clearly and accurately define the problem. This is what we mean by *problem analysis*. To get started on a problem solution, you must (1) clearly define the problem and the criteria for a successful solution, (2) identify what you know, (3) what you need to learn, and (4) identify any special constraints that apply or assumptions we must make. Only when you've clearly and accurately defined these parameters can you develop an effective plan for action.

PROBLEM ANALYSIS
Clearly define the problem and list the criteria for a successful solution.
What do we know about the problem?
What do we need to learn?
Are there any special constraints that apply or assumptions we must make?

II. Independent Research Whiteboard

Independent Research requires taking responsibility for acquiring the knowledge and skills identified in the problem analysis phase needed to solve the problem. This includes setting specific learning goals, dividing up the research tasks in a fair and effective manner, establishing timelines, and developing an effective strategy for acquiring the knowledge and skills needed to solve the problem.

INDEPENDENT RESEARCH
Specifically, what do we need to learn? (Make a list)
How will we divide up the learning between team members? Who will do what?
How much time do I have to complete my research?
What is my strategy for acquiring the knowledge and skills needed to solve the problem?

III. Brainstorming Whiteboard

Brainstorming involves applying what you've learned through your independent research in a group effort to generate possible solutions to the problem. By sharing your knowledge and ideas with others, you will be able to gauge your level understanding, integrate new information with your own prior knowledge, and converge on a solution that represents the collective knowledge of the group.

BRAINSTORMING			
Solution Ideas	Pros	Cons	Ranking
1			
2			
3			
4			

IV. Testing Your Idea Whiteboard

Testing your idea requires developing a viable test plan with specific performance criteria to validate your solution (i.e., How can you show that your solution actually solves the problem?). *One very important characteristic of a good test plan is that someone of reasonable intelligence can follow your plan and replicate your results.* If your test plan does not or cannot successfully validate your solution, the problem-solving process is repeated until an acceptable solution and test plan is developed.

TEST YOUR IDEA
List the criteria identified for a successful solution.
Indicate how your solution addresses each of the criteria listed.
Describe in detail how you would test your solution.
What equipment or resources would you need to test your solution?

Notes:

Final Challenge Report

Name: _____

Date: _____

Team Members: _____

The purpose of the Final Challenge Report is to help you summarize the process you used to solve the PBL Challenge. Reflecting on your experience is a powerful way to help you develop the problem-solving and critical thinking skills needed to become a productive life-long learner. Please be specific in describing the process that you and your team went through to solve the problem. Make sure you answer each question fully in paragraph form and use a spell-checker.

Using your completed *Whiteboards* as a guide, respond to the following:

- 1) **Problem Analysis:** Clearly describe the problem you had to solve. What specific criteria did your solution have to address? What did you know about the problem? What did you need to learn? Were there any special constraints that applied? What (if any) assumptions did you have to make to solve the problem? Explain.

- 2) **Independent Research:** What specifically did you need to learn? How did you break up the learning tasks among the members of your group? How did you budget your time? What was your strategy for acquiring the knowledge and skills needed to solve the problem? Was your learning strategy effective? Why or why not? How could you improve your learning strategy in the future? Explain.

- 3) **Brainstorming:** What ideas did you and your group come up for solving the problem? How did you decide on the best possible solution? How well did the members of your group function as a team? Did each member of the group contribute to the solution? Explain.

- 4) **Testing Your Idea:** Describe your solution in detail and explain how it addresses each of the criteria identified in the problem analysis phase. Describe your plan for testing your solution. What resources would you need to test your solution? Are there any limitations? Explain.

- 5) **Solution Quality:** How did your solution compare to the solution presented in the PBL Challenge? Was your solution effective? What (if anything) would you have done differently to improve your solution? Overall, what did you learn from this PBL Challenge?

PBL Problem Solving Rubric – Page 1

Problem-Solving Task	Excellent = 4	Good = 3	Fair = 2	Poor = 1	Score
Problem Analysis	<ul style="list-style-type: none"> • Student clearly and precisely defines problem parameters and criteria for success • Student correctly identifies all relevant knowledge and skills needed to solve problem • Student accurately identifies all relevant problem constraints • Student generates one or more creative and viable solution possibilities 	<ul style="list-style-type: none"> • Student adequately defines problem parameters and criteria for success • Student correctly identifies most relevant knowledge and skills needed to solve problem • Student accurately identifies most relevant problem constraints • Student generates one or more potentially viable solutions 	<ul style="list-style-type: none"> • Student defines some problem parameters and criteria for success • Student correctly identifies some relevant knowledge and skills needed to solve problem • Student identifies some relevant problem constraints • Student generates one or more questionable solution possibilities 	<ul style="list-style-type: none"> • Student incorrectly defines problem parameters and criteria for success • Student incorrectly identifies relevant knowledge and skills needed to solve problem • Student incorrectly identifies problem constraints • Student generates solution possibilities that are either unrealistic or incorrect 	
Self-Directed Learning	<ul style="list-style-type: none"> • Student correctly articulates specific and appropriate learning objectives • Student correctly identifies all required instructional resources • Student has a clear and realistic plan for learning • Student has a clear and realistic plan for monitoring his/her comprehension 	<ul style="list-style-type: none"> • Student correctly articulates specific learning objectives • Student correctly identifies most required instructional resources • Student has an adequate plan for learning • Student has an adequate plan for monitoring his/her comprehension 	<ul style="list-style-type: none"> • Student articulates questionable learning objectives • Student correctly identifies some required instructional resources • Student has an a rudimentary plan for learning that needs to be more fully developed • Student has a rudimentary plan for monitoring his/her comprehension that needs to be more fully developed 	<ul style="list-style-type: none"> • Student articulates learning objectives that are irrelevant and/or incorrect • Student identifies instructional resources that are irrelevant and/or incorrect • Student has inadequate or no plan for learning • Student has inadequate or no plan for monitoring comprehension 	
Brainstorming	<ul style="list-style-type: none"> • Student generates numerous viable alternative solutions • Student demonstrate effective collaboration and teamwork skills • Student accurately and correctly identify valid pros and cons • Students precisely and methodically evaluate and rank alternative solutions • Students articulate a clear and concise plan of action for enacting their solution 	<ul style="list-style-type: none"> • Student generate numerous alternative solutions • Student demonstrates adequate collaboration and teamwork skills • Student identifies some valid pros and cons • Students adequately evaluate and rank alternative solutions • Students articulate an adequate plan of action for enacting their solution 	<ul style="list-style-type: none"> • Student generate some alternative solutions that need to be more thoroughly developed • Student demonstrates collaboration and teamwork skills that need refinement • Student identifies some pros and cons but needs to improve process • Students evaluate and rank alternative solutions but methods need improvement • Students articulate a plan of action for enacting their solution that needs refinement 	<ul style="list-style-type: none"> • Student generates inadequate or no alternative solutions • Student demonstrates poor collaboration and teamwork skills • Student either do not identify some pros and cons or do so incorrectly • Students do not evaluate and rank alternative solutions • Students articulate no plan of action for enacting their solution 	

PBL Problem Solving Rubric – Page 2

Problem-Solving Task	Excellent = 4	Good = 3	Fair = 2	Poor = 1	Score
Test Solutions	<ul style="list-style-type: none"> • Test plan clearly and correctly addresses all solution criteria • Test plan has a well defined and realistic timeline • Testing methods and procedures are appropriate and valid • All testing resources are clearly identified and appropriate • Solution benchmarks are clearly identified and measurable 	<ul style="list-style-type: none"> • Test plan clearly and correctly addresses most solution criteria • Test plan has an adequate and realistic timeline • Testing methods and procedures are appropriate and valid • Most testing resources are identified and appropriate • Solution benchmarks are identified and mostly measurable 	<ul style="list-style-type: none"> • Test plan addresses some solution criteria • Test plan has a timeline that needs refinement • Testing methods and procedures are provided but need improvement • Testing resources need to be more clearly identified • Solution benchmarks are identified but need refinement 	<ul style="list-style-type: none"> • Test plan does not addresses solution criteria • Test plan does not have timeline • Testing methods and procedures are either not provided or are incorrect • Testing resources are not identified • Solution benchmarks are not identified 	
Solution Quality	<ul style="list-style-type: none"> • Solution clearly and effectively addresses all stated criteria and exceeds performance benchmarks • Solution represents a realistic and cost effective means of addressing problem • Solution is novel, creative and reflects exemplary problem solving and critical thinking skills • Solution can be easily replicated 	<ul style="list-style-type: none"> • Solution effectively addresses most stated criteria and meets most performance benchmarks • Solution represents a realistic means of addressing problem • Solution shows creativity and reflects good problem solving and critical thinking skills • Solution can be easily replicated with some effort 	<ul style="list-style-type: none"> • Solution addresses some stated criteria and meets some performance benchmarks • Solution represents a means of addressing the problem but needs improvement • Solution is shows marginal problem-solving and critical thinking skills • Solution can be replicated but with considerable effort 	<ul style="list-style-type: none"> • Solution does not address stated criteria and/or does not meet performance benchmarks • Solution represents an invalid or ineffective means of addressing the problem • Solution is shows poor problem solving and critical thinking skills • Solution cannot be replicated without major revisions 	
Comments:					Total Score

Concept Mapping

Concept Mapping Instructions

Concept mapping is a graphical technique used to assess students' conceptual knowledge. While there are a number of different approaches available in the literature and on the Internet, we have adopted a modified version of the method employed by the VaNTH (Vanderbilt University, Northwestern University, University of Texas, and Harvard University) Engineering Research Center.

Concept maps can be created using an "open-ended" approach in which students generate and map their own list of concepts related to a particular topic, or using a more structured approach whereby the instructor provides students with a list of concepts to be mapped. In our approach, we provide students with the list of concepts related to a particular PBL challenge in order to limit variability. A complete list of main concepts and sample concepts maps for each PBL challenge is located in the "Teacher Resources" section of each PBL challenge.

How do I construct a concept map?

The following example illustrates how to instruct students to construct a concept map for the PhotoMachining Challenge.

Example

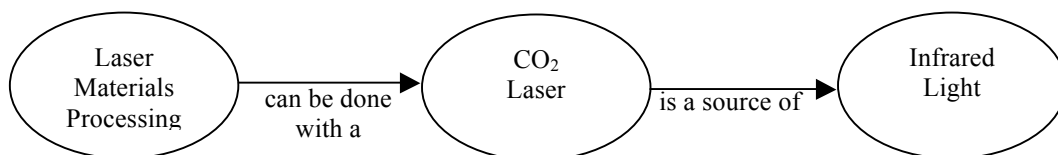
Problem: How do we strip a 50 um wire with a laser?

PhotoMachining Concepts

CO ₂ Laser	Wavelength	Lenses	Accuracy
Excimer Laser	Absorption	Mirrors	Tolerance
Ablation	Reflection	Mask	Wire Stripping
Irradiance	Infrared	Magnification	Ultraviolet
Beam Delivery			

Instructions

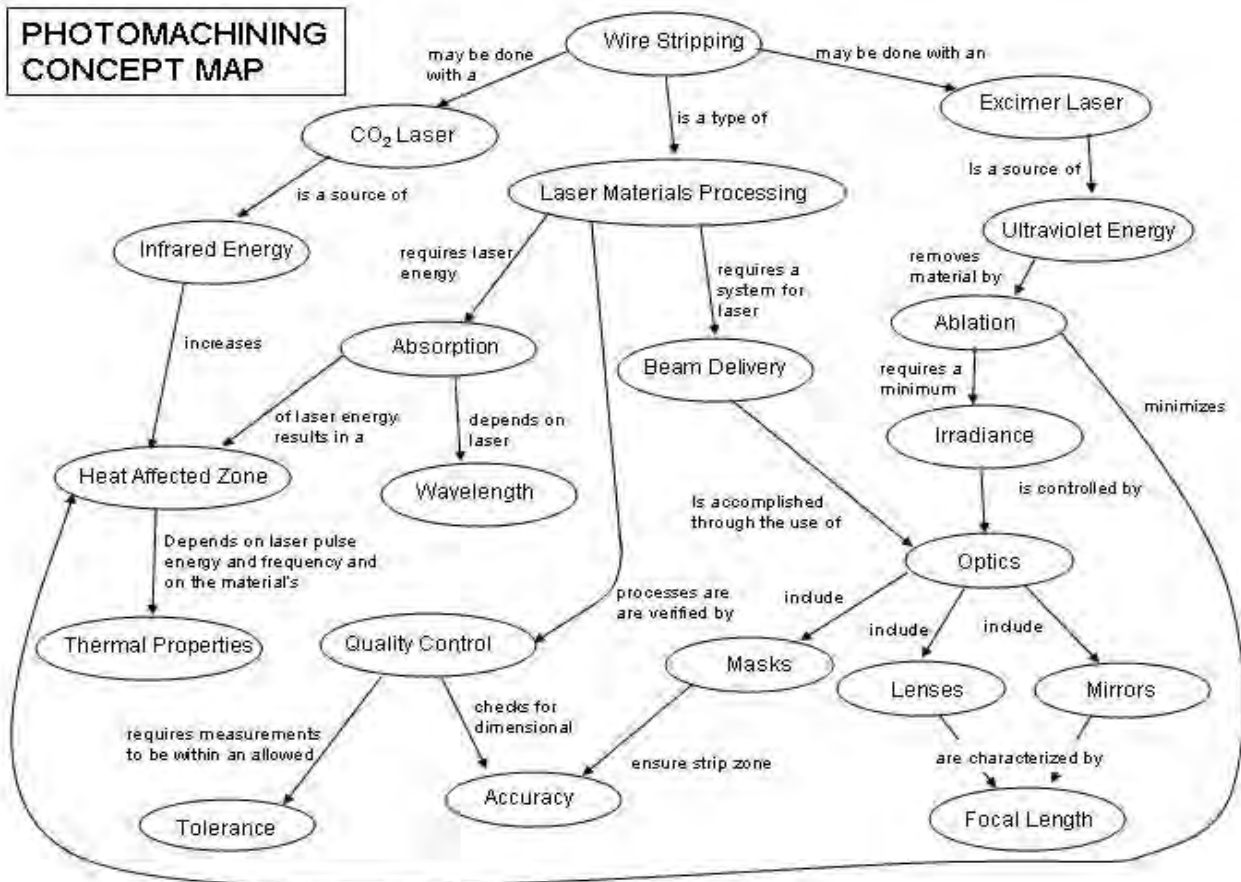
1. From the list of concepts shown above, organize and group related concepts in a hierarchal fashion on a whiteboard or piece of paper.
2. Connect related concepts using lines with arrows that show the direction of the relationship
3. Label each line with words or short phrases that describe the relationship between the two concepts. **IMPORTANT:** Each relationship between any two concepts should form a complete proposition. For example:



Propositions generated:

- Laser materials processing can be done with a CO₂ laser.
- CO₂ laser is a source of infrared light.

4. Examine the linkages to make sure each relationship forms a valid proposition.
5. Rearrange and/or remove concepts to simplify and clarify the concept map
6. When you are satisfied with your concept map, make sure it is NEAT and CLEAR and list each proposition formed on a separate sheet. (Instructor: See attached example).



Propositions Generated

1. Wire stripping is a type of laser materials processing.
2. Laser materials processing requires a system for laser beam delivery.
3. Beam delivery is accomplished through the use of optics.
4. Wire stripping may be done with a CO₂ laser.
5. A CO₂ laser is a source of infrared energy.
6. Infrared energy increases heat affected zone.
7. Wire stripping may be done with an excimer laser.
8. An excimer laser is a source of ultraviolet energy.
9. Ultraviolet energy removes material by ablation.
10. Ablation requires a minimum irradiance.
11. Ablation minimizes heat affected zone.
12. Irradiance is controlled by optics.
13. Optics include mirrors.
14. Optics include lenses.
15. Optics include masks.
16. Lenses and mirrors are characterized by focal length.
17. Masks ensure strip zone accuracy.
18. Laser materials processing requires laser energy absorption.
19. Absorption depends on laser wavelength.
20. Absorption of laser energy results in a heat affected zone.
21. Heat affected zone depends on laser pulse energy and frequency and on the material's thermal properties.
22. Laser materials processing processes are verified by quality control.
23. Quality control checks for dimensional accuracy.
24. Quality control requires measurements to be within an allowed tolerance.

PBL Concept Map Scoring Rubric

Assessment Criteria*	Excellent = 4	Good = 3	Fair = 2	Poor = 1	Score
Concept Validity (use only when concepts are not provided to students)	<ul style="list-style-type: none"> Student correctly identifies all relevant concepts and items related to the topic. 	<ul style="list-style-type: none"> Student correctly identifies most relevant concepts and items related to the topic 	<ul style="list-style-type: none"> Student correctly identifies some relevant concepts and items related to the topic 	<ul style="list-style-type: none"> Student correctly identifies few or no relevant concepts and items related to the topic 	
Proposition Validity	<ul style="list-style-type: none"> All propositions are complete and valid. Linking lines connect related terms and point in correct direction. Linking words accurately describe relationship between concepts. Student shows a deep understanding of the relationship between concepts. All or most concepts are linked to more than one related concept. 	<ul style="list-style-type: none"> Most propositions are complete and valid. Most linking lines connect properly. Most linking words accurately describe the relationship between concepts Student shows a good understanding of the relationship between concepts. Most concepts are linked to more than one related concept. 	<ul style="list-style-type: none"> Correct but incomplete propositions. Linking lines not always pointing in correct direction. Linking words are absent or don't clarify relationships between concepts. Student shows a partial understanding of the relationship between concepts. Some concepts are linked to more than one related concept. 	<ul style="list-style-type: none"> Few or no valid propositions. Linking lines do not point in correct direction. Linking words are absent or incorrectly identify relationships between concepts. Student shows a lack of understanding of the relationship between concepts. Some concepts are not linked to more than one related concept. 	
Presentation	<ul style="list-style-type: none"> Concept map is neat, clear, legible, and has easy to follow links. No spelling or grammatical errors. 	<ul style="list-style-type: none"> Concept map is neat, clear, legible, and has easy to follow links. Has some spelling or grammatical errors. 	<ul style="list-style-type: none"> Concept map is messy and has somewhat difficult to follow links. Has many spelling or grammatical errors. 	<ul style="list-style-type: none"> Concept map is sloppy and links are difficult or impossible to understand. Has many spelling or grammatical errors. 	
Comments:					Total Score

* Assessment criteria weighting is based on instructor discretion