PBL Challenge
Implementation Guide

Version 1.5.1

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Created by

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PBL CHALLENGE IMPLEMENTATION GUIDE

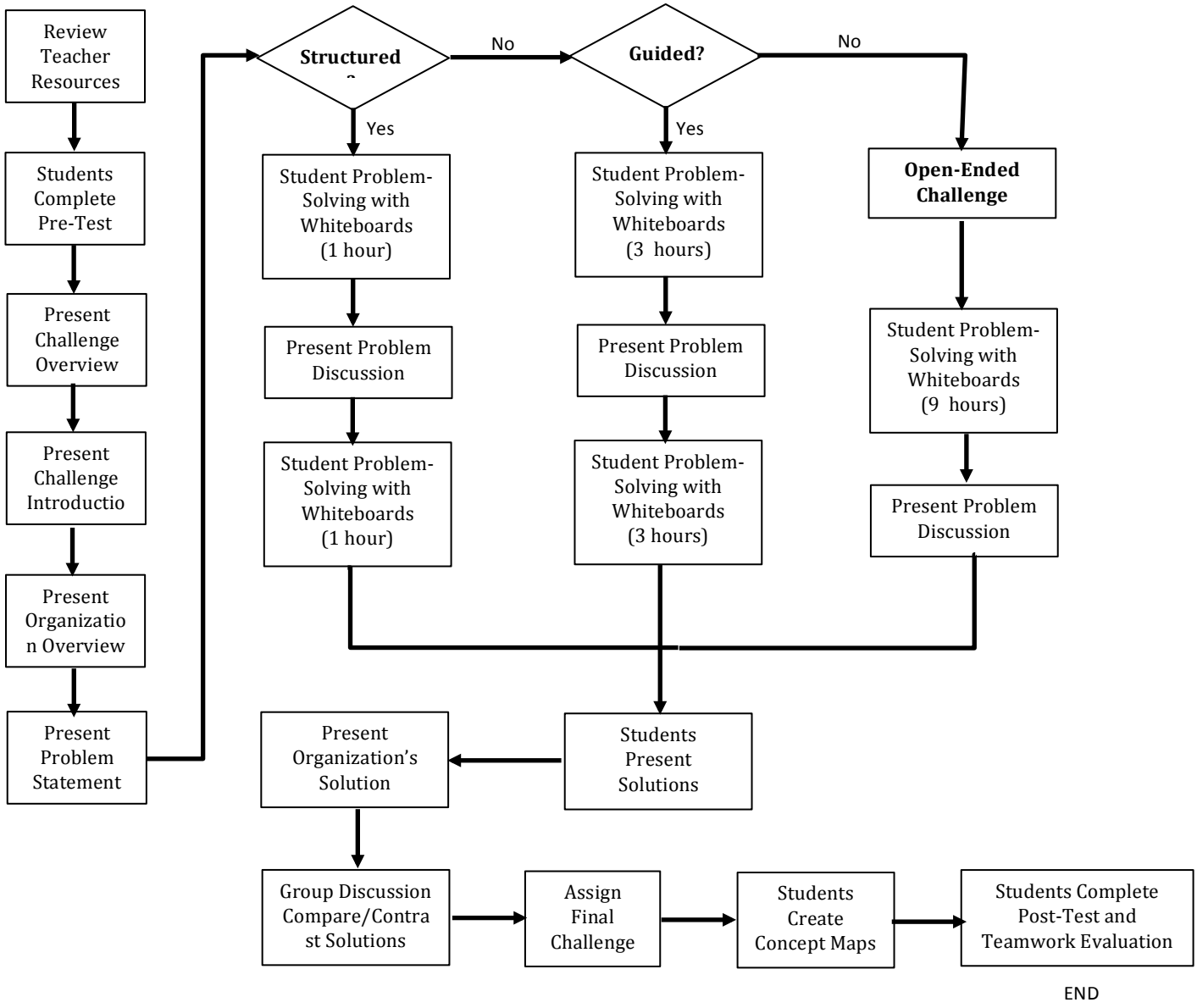


Figure 1 – The PBL Challenge Implementation Guide in flowchart form

Introduction to the PBL Challenges

The PBL Challenges are located at the following website:

http://www.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

See Table 1 for a description of each PBL Challenge page.
See Figure 2 for the PBL Challenge site map.

PBL Challenge Resource Pages

Each PBL Challenge contains instructional resources for teachers (**Teacher Resources**) and a problem-solving resource (**Problem-Solving Toolbox**) for students.

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 four-pronged assessment tool that includes a question bank with solutions, a concept-mapping exercise with instructions, a problem-solving assessment tool and a teamwork evaluation. 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*** – Information on alignment to national science and technology literacy standards.
   e. ***Updates*** – Updates on new technologies that affect the organization's solution.

   For more information on Teacher Resources, see Table 2.

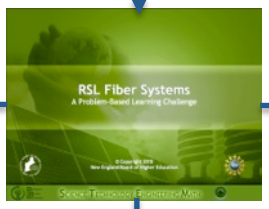
2) **Problem-Solving Toolbox:** *Link on Problem Statement and Problem Discussion pages*
   a. ***The Whiteboards*** – A tool for developing student problem- solving skills.
   b. ***Additional Resources*** – Valuable additional information located on each Challenge slide.

   For more information on the Problem-Solving Toolbox, see Table 3.

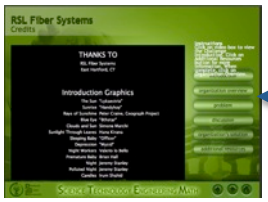
NEBHE PBL CHALLENGE SITE MAP

Title Page

Overview



Credits



Teacher Resources

Challenge Introduction

Introduction Resources

The Whiteboards

Organization Overview

Organization Resources

Problem Statement

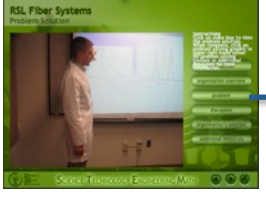
Problem Resources

Problem Solving Toolbox

Discussion

Discussion Resources

Organization's Solution



Solution Resources

Implementation Instructions

The PBL Challenges use 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. In general, students who are new to the PBL challenges should begin using the *structured* approach, then progress to the *guided* approach, and finally to 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 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 examples are based on a three-hour lecture/ three-hour 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 three-hour lab class plus one to three hours follow-up*
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 three-hour lab period with follow up review during the next class. Prior to the class in which you introduce the Challenge, assign homework problems from the question bank located in the **Teacher Resources** section as a pre-assessment.

STEPS:

Class I

1. Present **Introduction** video and review additional resources with students. This segment sets the context for the problem to follow.
2. Present **Company/University Overview** video and review additional resources with students. This segment shows that the problem was solved by engineers, scientists, and technicians in a real workplace.
3. Present **Problem Statement** video and review additional resources with students.
4. Explain the **Problem-Solving Toolbox** and introduce the **Whiteboards**.
5. Break the class into small teams of three to four students and instruct the students to complete each of the four Whiteboards to the best of their ability. Instruct students to:
    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.

6. Allow approximately one 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.

7. Reconvene class and present the **Problem Discussion**. Provide students with the Problem Discussion password so that they can watch the video again and use the **Additional Resources** to seek out additional information. Break students into their teams again and continue group problem solving session using the Whiteboards by filling in any missing information. Allow additional time (approximately one hour) for students to continue to work towards their solutions. 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.
8. **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. (Timing: Approximately 5 minutes for each student.)
9. Present the **Organization's Solution** video to the class and provide them with Problem Solution password so that they can review the solution on their own. Conduct a group discussion to compare and contrast solutions. Emphasize that real problems often have many solutions, but not all are equally appropriate to a given situation. (Timing: Approximately 30 minutes.)
10. Assign students the **Final Challenge Report** as a homework assignment. Provide them with the **Final Challenge Report Scoring Rubric** to guide their report preparation.

Class II

11. Break students into small groups (three to four students) and guide them in creating a Concept Map for the Challenge (concept mapping instructions are provided in **Teacher Resources** section. Provide students with **Concept Map Scoring Rubric** to guide their work. (Timing: Allow approximately one to three hours in class or assign for homework.)

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

13. Have students complete the **Teamwork Evaluation**.

B. Guided Challenge (Instructor-Guided):

Estimated Time for Completion: *Two three-hour classes plus one to three hours 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 the *structured* approach, but student groups work with limited instructor supervision and are given 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, while at the same time providing a safety net so that learning occurs without risk of failure. Prior to the class in which you introduce the Challenge, 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 1-5**. Have students complete the **Whiteboards**. Reiterate that it is *extremely important* to be as thorough as possible. Allow a complete three-hour class session for this activity and encourage students to continue their work outside of class.

Class II

2. Present the **Problem Discussion** to the class and provide students with the Problem Discussion password. 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 providing answers. At this point, students should be well on their way to converging on their problem solutions and test plans, and should begin creating their PowerPoint solution presentations.

Class III

3. **Student Presentations**: Have students present their solutions in a formal PowerPoint presentation. As in the *structured* approach, students should describe the process (referring to the **Whiteboards**) they used to solve the problem. (Timing: Approximately 10 minutes per student.)

4. Repeat **Structured Approach Steps 9-13**.

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

Estimated Time for Completion: *Three three-hour classes plus one to three hours 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. Students are provided *only* with information from the **Introduction**, **Organization 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 **Organization's Solution** revealed. Student solutions are then compared and contrasted with the organization's solution in a group discussion that includes recommendations for improvement.

STEPS:

Class 1

1. Repeat **Structured Challenge Steps 1-6**. Reiterate the importance of being as thorough as possible when completing the **Whiteboards**. Allow two to three complete class periods (three to six hours total) 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 PowerPoint 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. (Timing: Approximately 15 minutes per student.)
4. Repeat **Structured Approach Steps 9-13**.

II. Assessment

The PBL Challenges include four student assessment measures: (1) content knowledge, (2) conceptual knowledge, (3) problem-solving ability, and (4) teamwork. Instructions 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 questions pertaining to technical content associated with each Challenge is available in the **Teacher Resources** section. We recommend pre-and post-testing with each Challenge in order to provide a measure of improvement in content knowledge.

B. Conceptual Knowledge

Conceptual knowledge is assessed through concept mapping. Each Challenge contains a list of main concepts, a reference concept map (for instructors), 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 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 have 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 used 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.

D. Teamwork

Students rank each team member, including themselves, on several measures of performance. The assessment sequence is illustrated in Figure 3.

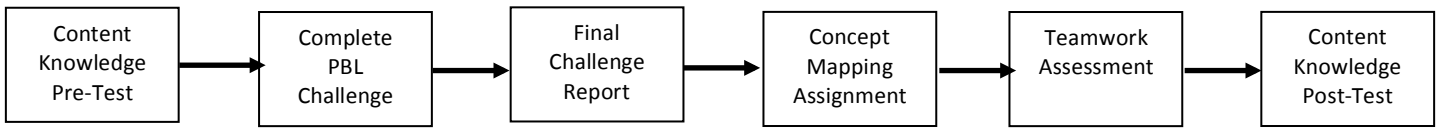


Figure 3 – Assessment Sequence

Calculating Student Grades

Total Score

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

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

where w_1, w_2, w3 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, problem solving ability, and teamwork can be found in the **Teacher Resources** section of each Challenge under *Assessment Strategies*.

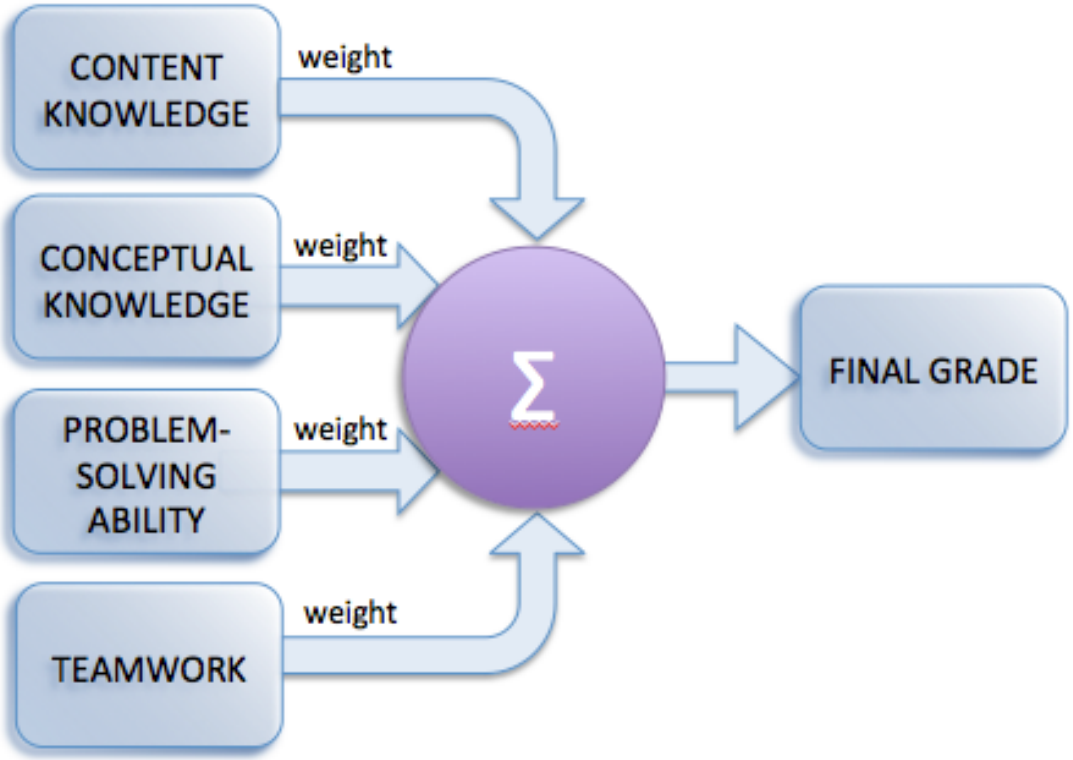


Figure 4 – Student Assessment in PBL

Table 1 - PBL Challenge Main Challenge Pages

Challenge Page 1 **PBL Challenge Front Page**	
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.	
Challenge Page 3 **PBL Challenge Introduction** This page provides a multimedia introduction to the science and technology being addressed in the Challenge.	
Challenge Page 4 **Organization Overview** This page provides a multimedia tour of the sponsoring organization to provide the student with a brief overview of the context in which the problem was solved.	

Table 1 - PBL Main Challenge Pages - Continued

Challenge Page 5 **Problem Statement** This page provides a multimedia re-enactment of the problem as it was originally presented to provide students with a brief overview of the context in which the problem was solved.	
Challenge Page 6 **Problem Discussion** 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 instructor provides the password at a point in the challenge activity when students conclude that more information is needed to solve the problem.	
Challenge Page 7 **Organization's Solution** This **password-protected** page provides a multimedia presentation of the actual problem solution developed by the Challenge partner. 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.	

Table 2 – PBL Teacher Resources

Teacher Resources Page The Teacher Resources Page contains four links: 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 Resources**: Videos, Khan Academy math alignment, stories of how teachers have implemented this Challenge in the classroom and other aids to classroom implementation 4. **Standards Alignment**: Alignment with National Science and Technological Literacy standards and SME Advance Manufacturing Core Competencies 5. **Grade level adaptation:** How to use the Challenges at the middle school level.	
Teacher Resources Page **Assessment Strategies** 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.	

Table 3 - PBL Problem-Solving Toolbox

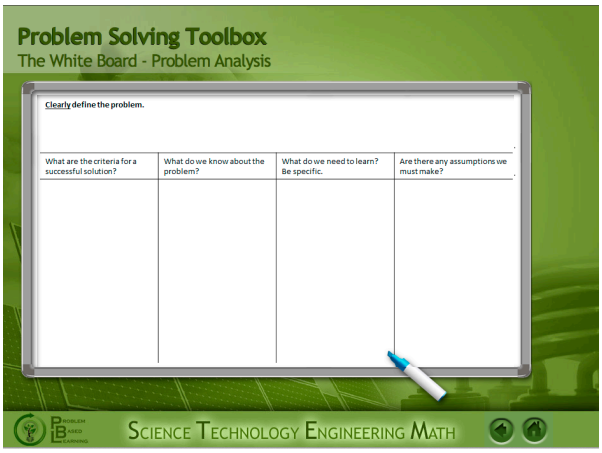
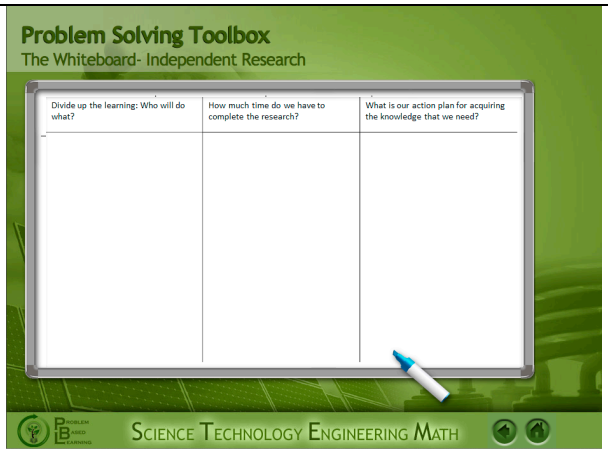
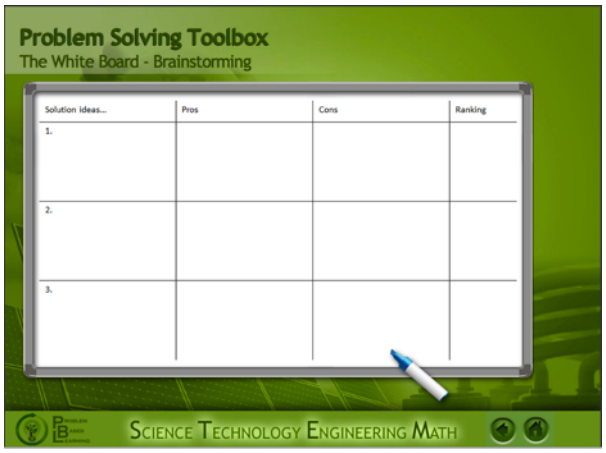
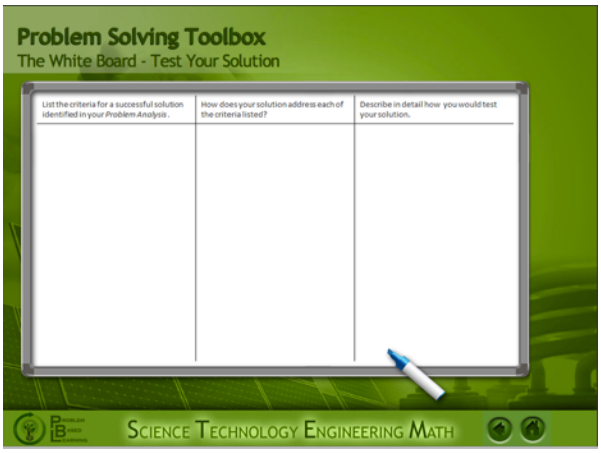
Problem-Solving Toolbox Slide 1 **The Problem-Solving Cycle** The Problem-Solving Toolbox is designed to help students develop a systematic method for solving ill-structured problems. Problem-solving is a recursive process involving four main steps: (1) Problem analysis, (2) Independent Research, (3) Brainstorming, and (4) Testing 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 or they may be downloaded and printed.	
Problem-Solving Toolbox Slide 2 **The Problem Analysis Whiteboard** The first step in problem solving is to clearly define the problem. Exactly what is the problem you are trying to solve and what is the desired outcome? To do this, you must first identify and list the criteria against which your solution will be measured. You must identify what you know about the problem (i.e., what is given), what you need to learn to solve the problem and any assumptions you need to make if information is missing. Once you have clearly defined the problem, you are ready to move forward and seek out the knowledge and skills needed to solve the problem.	
Problem-Solving Toolbox Slide 3 **The Independent Research Learning Whiteboard** Independent Research involves developing a plan to acquire the knowledge you identified in Step 1 as necessary to solve the problem. Divide up the learning with your team members, set deadlines and develop an action plan for how you and your team will acquire the knowledge and skills needed to solve the problem.	

Table 3 - PBL Problem-Solving Toolbox - Continued

Problem-Solving Toolbox Slide 4 **The Brainstorming Whiteboard** *Brainstorming* involves sharing what you've learned through your independent research with your team in order to generate possible solutions. This requires carefully listening to and considering the input of your teammates—it is important to exchange ideas without criticism or judgment. Through this process, you will be able to identify a solution that represents the collective knowledge of the group.	
Problem-Solving Toolbox Slide 5 **The Testing Your Idea Whiteboard** *Testing your idea* requires developing a detailed plan to validate your solution based on the criteria you defined in the Problem Analysis phase. *A good test plan is one that someone of reasonable intelligence can follow and replicate your results.* In cases where it is unrealistic to test your solution, you should provide conclusive evidence describing how your solution addresses each of the stated criteria.	

APPENDIX

- Challenge Passwords
- PBL Projects Online Resources
- The Whiteboards
- Final Challenge Report and Scoring Rubric
- Concept Mapping Instructions and Scoring Rubric
- Teamwork Peer Evaluation Form

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):

Fenna Hanes
Email: fhanes@nebhe.org
Phone: 617-357-9620 x 129

PBL Project Online Resources

PBL Projects is on YouTube, Twitter and LinkedIn. Find the links on the left side of the home page at www.pblprojects.org website.

On our YouTube channel are a "How-To" video, a video documenting PBL use in a classroom, interviews with Challenge industry partners and more.

The Whiteboards

Rapid advances in technology require individuals in science, technology, engineering and mathematics (STEM) fields careers to skillfully apply their problem-solving knowledge to novel situations. But what does it mean to be a good problem solver? Problem solving has been described as “knowing what to do when you don’t know what to do.” A good problem solver is someone who can approach any problem in a systematic way: dissecting and analyzing it, and formulating a coherent and viable strategy for developing a solution. Good problem solvers are patient and methodical, carefully considering all options before moving forward toward a solution. They break complex problems down into smaller, more manageable steps, making reasoned decisions on how to approach each step. Good problem solvers manage the problem solving process by planning, monitoring, and evaluating their progress and strategies, and adjusting their approaches when necessary. [1]

The *Whiteboards* were developed with the help of industry partners to help you improve your problem solving ability by walking you through a four-step process consisting of problem analysis, independent research, brainstorming, and solution testing.

The Problem Solving Cycle

Step I. Problem Analysis

The first step in problem solving is to clearly define the problem. Exactly what is the problem you are trying to solve and what is the desired outcome? To do this, you must first identify and list the criteria against which your solution will be measured. You must identify what you know about the problem (i.e., what is given), what you need to learn to solve the problem and any assumption you need to make if information is missing. Once you have clearly defined the problem, you are ready to move forward and seek out the knowledge and skills needed to solve the problem.

Clearly define the problem:			
What are the criteria for a successful solution?	**What do we know about the problem?**	**What do we need to learn? Be specific.**	**Are there any assumptions we must make?**

Step II. Independent Research

Independent Research involves developing a plan to acquire the knowledge you identified in Step 1 as necessary to solve the problem. Divide up the learning with your team members, set deadlines and develop an action plan for how you and your team will acquire the knowledge and skills needed to solve the problem.

Divide up the learning: Who will do what?	**How much time do we have to complete the research?**	**What is our action plan for acquiring the knowledge we need?**

Step III. Brainstorming

Brainstorming involves sharing what you've learned through your independent research with your team in order to generate possible solutions. This requires carefully listening to and considering the input of your teammates—it is important to exchange ideas without criticism or judgment. Through this process, you will be able to identify a solution that represents the collective knowledge of the group.

Solution ideas	**Pros**	**Cons**	**Ranking**

STEP IV. Testing Your Idea

Testing your idea requires developing a detailed plan to validate your solution based on the criteria you defined in the Problem Analysis phase. *A good test plan is one that someone of reasonable intelligence can follow and replicate your results.* In cases where it is unrealistic to test your solution, you should provide conclusive evidence describing how your solution addresses each of the stated criteria.

List the criteria for a successful solution identified in your *Problem Analysis.*	**How does your solution address each of the criteria listed?**	**Describe in detail how you would 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 and your team used to solve the PBL Challenge. Please be specific in describing the process. Reflecting on your experience is a powerful way to help you develop the problem-solving and critical thinking skills needed to become a good life-long learner. 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 team? How did you budget your time? What was your strategy for acquiring the knowledge and skills needed to solve the problem? What resources did you use (e.g., Internet, textbooks, journals, etc.)? Was your learning strategy effective? Why or why not? 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 did your group function as a team? Did each member of the group effectively 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/validating 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	• 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.	• 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.	• 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.	• 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	• 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.	• 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.	• 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.	• 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	• 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.	• 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.	• Student generates 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.	• 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	• 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.	• 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.	• 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.	• 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	• 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.	• 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.	• 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.	• 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 (**Va**nderbilt University, **N**orthwestern University, University of **T**exas, and **H**arvard 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 third approach provides students with some of the concepts and asks them to provide a number of their own. 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 RSL Fiber Systems Challenge.

Example

Problem: Design an energy efficient and ergonomic lighting system for a submarine workstation.

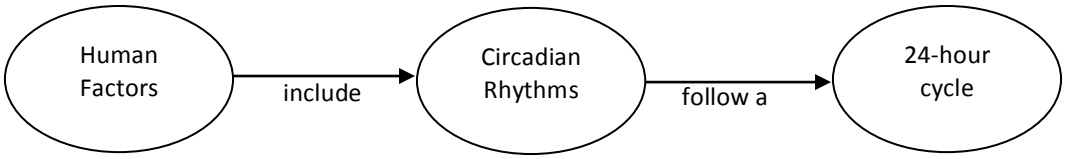
RSL Fiber Systems Concepts

Submarine lighting	Natural light	24 hour cycle	White LEDs
Energy efficient	Color temperature	Body temperature	RGB Multiemitter
Ergonomic	Wavelength	Hormone production	Optical fiber
Human factors	Decibels	Sleep/wake cycle	Loss
Circadian rhythms	Kelvins	Illuminance	

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.

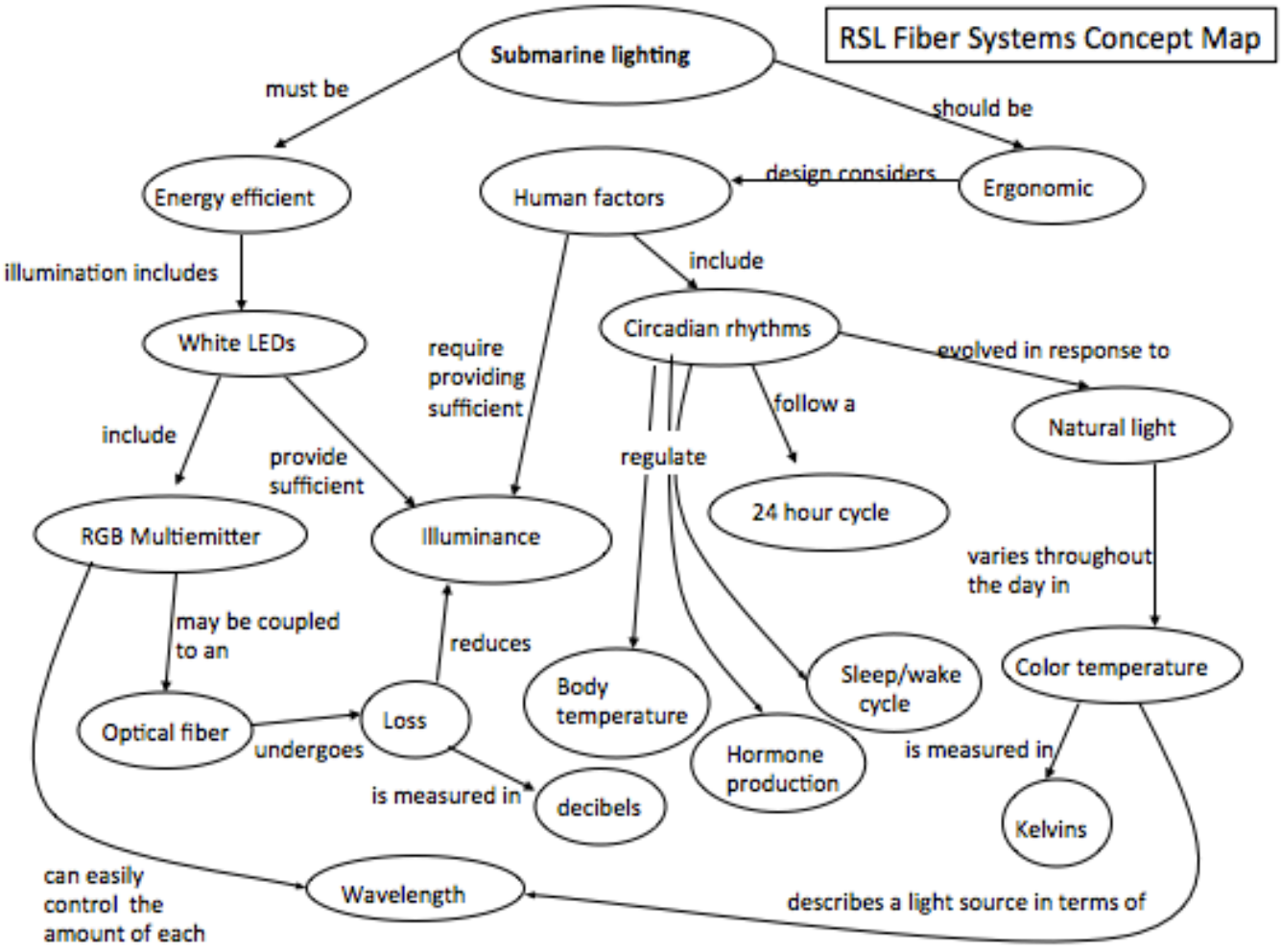
3. Label each line with words or short phrases that describe the relationship between the two concepts. **IMPORTANT:** Each relationship between any two concepts should form a complete proposition (sentence). For example:



Propositions generated:

- Human factors include circadian rhythms.
- Circadian rhythms follow a 24-hour cycle.

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. Submarine lighting must be energy efficient.
2. Energy efficient lighting includes white LEDs.
3. White LEDs provide sufficient illumination.
4. White LEDs include RGB multiemitters
5. RGB multiemitters may be coupled to an optical fiber.
6. Optical fiber undergoes loss.
7. Loss is measured in decibels
8. RGB multiemitters can easily control the amount of each wavelength.
9. Loss reduces illuminance.
10. Submarine lighting should be ergonomic
11. Ergonomic design considers human factors.
12. Human factors require providing sufficient illuminance.
13. Human factors include circadian rhythms.
14. Circadian rhythms regulate body temperature.
15. Circadian rhythms regulate hormone production.
16. Circadian rhythms regulate sleep/wake cycle.
17. Circadian rhythms follow a 24 hour cycle.
18. Circadian rhythms evolved in response to natural light.
19. Natural light varies throughout the day in color temperature.
20. Color temperature is measured in Kelvins.
21. Color temperature describes a light source in terms of wavelength.

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)	• Student correctly identifies all relevant concepts and items related to the topic.	• Student correctly identifies most relevant concepts and items related to the topic.	• Student correctly identifies some relevant concepts and items related to the topic.	• Student correctly identifies few or no relevant concepts and items related to the topic.	
Proposition Validity	• 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.	• 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.	• 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.	• 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	• Concept map is neat, clear, legible, and has easy to follow links. • No spelling or grammatical errors.	• Concept map is neat, clear, legible, and has easy to follow links. • Has some spelling or grammatical errors.	• Concept map is messy and has somewhat difficult to follow links. • Has many spelling or grammatical errors.	• Concept map is sloppy and links are difficult or impossible to understand. • Has many spelling or grammatical errors.	
Comments:				**Total Score**	

PBL Teamwork Peer Evaluation Form

Name _____ Date_____
Project Title _____

Instructions

Using the following 5-point rating scale, please rate each of your team members' performance as well as your own performance on the PBL Challenge for the four categories (A-E) listed below. When complete, add the results for a total score. Your response is **confidential** and will not be shared with any of your team members.

Rating Scale:

1 = Never 2 = Sometimes 3 = Often 4 = Most of the time 5 = Always

Performance Categories

When working on the PBL Challenge, my team member:

A. Completed specific tasks on time
B. Did his/her fair share of the work
C. Produced work of acceptable quality
D. Actively contributed to the team effort during class
E. Actively contributed to the team effort outside of class time

	Rating					
Team Member Name	**A**	**B**	**C**	**D**	**E**	**Total**
_____	+	+	+	+	=	
_____	+	+	+	+	=	
_____	+	+	+	+	=	
*Your Own Performance*_____	+	+	+	+	=	

Additional Comments:

Teamwork Evaluation Form adapted from: Lavel, D., and Cradiz, D. (1999). "Evaluating Student Teamwork on Projects: The Use of Behaviorally Anchored Scales to Evaluate Student Performance. Eric Document ED 424 250.