Problem-Based Learning: A Practical Approach for STEM Education

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Problem-Based Learning: A Practical Approach for STEM Education

The Photon PBL Project

What is Problem-Based Learning?

Used extensively in medical education since the early 1970's, PBL teaches students the process of solving genuine real-world problems by:

- Collaboratively analyzing and framing the problem
- Engaging in self-directed learning
- Brainstorming possible solutions
- Testing hypotheses
- Converging on an optimal solution

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Characteristics of PBL:

- Learning is student centered
- Learning occurs in small groups
- A tutor acts as facilitator
- Authentic problems are presented *before* any preparation or study has occurred
- The problem itself drives the learning
- New information is acquired via self-directed learning

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Benefits of Problem-Based Learning:

- Improves students' understanding and retention of knowledge
- Promotes a "deep approach" to learning
- Improves critical thinking and problem solving skills
- Improves motivation for learning
- Improves students' ability to transfer skills and knowledge to new situations

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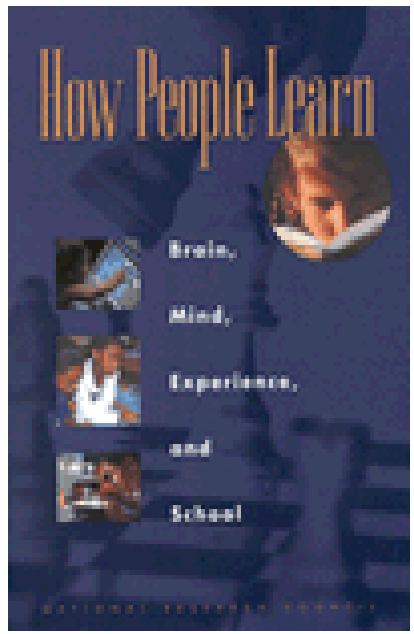
PBL addresses Bransford's *How People Learn* findings:

1. People come to learning experiences with preconceptions. Uncovering prior knowledge allows preconceptions to be examined and misconceptions recognized.
2. Learning concepts and skills within a meaningful context enables students to organize their learning in ways that facilitate retrieval and application.
3. Metacognition, or thinking about how one thinks, is essential for reflective practice to develop



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The many faces of PBL: *What's the difference?*

Inquiry-Based Methods

- **Problem-based learning** – Students work in teams to solve authentic ill-structured problems before being formally introduced to concepts
- **Project-based learning** – Student apply previously acquired knowledge to solve a specific problem
- **Case-based learning** – Students study historical or hypothetical cases involving scenarios likely to be encountered in professional practice.
- **Discovery learning** – Students work independently on problem solutions with little or no instructor direction. *Guided discovery* provides some instructor direction

Source: Prince & Felder, The many faces of inductive teaching and learning, *Journal of College Science Teaching, March/April 2007*

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A good PBL problem should…

- Be open-ended with more than one possible solution
- Be ill-structured, with insufficient information to facilitate inquiry
- Engage students' interest, and motivate them to probe for deeper understanding of the concepts being introduced
- Be based on real-world issues and situations
- Require cooperation and teamwork among team members
- Be linked to prior knowledge

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The problem with PBL…

- PBL thrusts students into an uncertain, self-directed learning environment where the responsibility for learning is placed on the student, often eliciting fear and anxiety
- Frustration and anxiety can lead to disengagement from the learning process among students and can create a stressful situation for faculty trying to transition to PBL from more traditional instructional methods

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Addressing the problem…

The Photon PBL Project

- **Three year NSF ATE project ($750,000)**
- **Project Goals:**
  - Create 8 multimedia PBL “Challenges” in photonics technology in collaboration with photonics industry and university partners
  - Recruit and train over 28 (now over 50) HS & college STEM educators to field test PBL Challenges in their classrooms
  - Create a comprehensive teacher’s guide for implementing PBL Challenges in STEM classrooms
  - Conduct research on the efficacy of PBL in STEM education

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Photon PBL Challenge Structure:

Three levels of difficulty (or autonomy) designed to scaffold the development of students' problem solving skills.

- **Level 1 (Structured)** – Case Study
- **Level 2 (Guided)** – Guided Inquiry
- **Level 3 (Open-Ended)** – Traditional PBL

Instructor controls access to information through password protection

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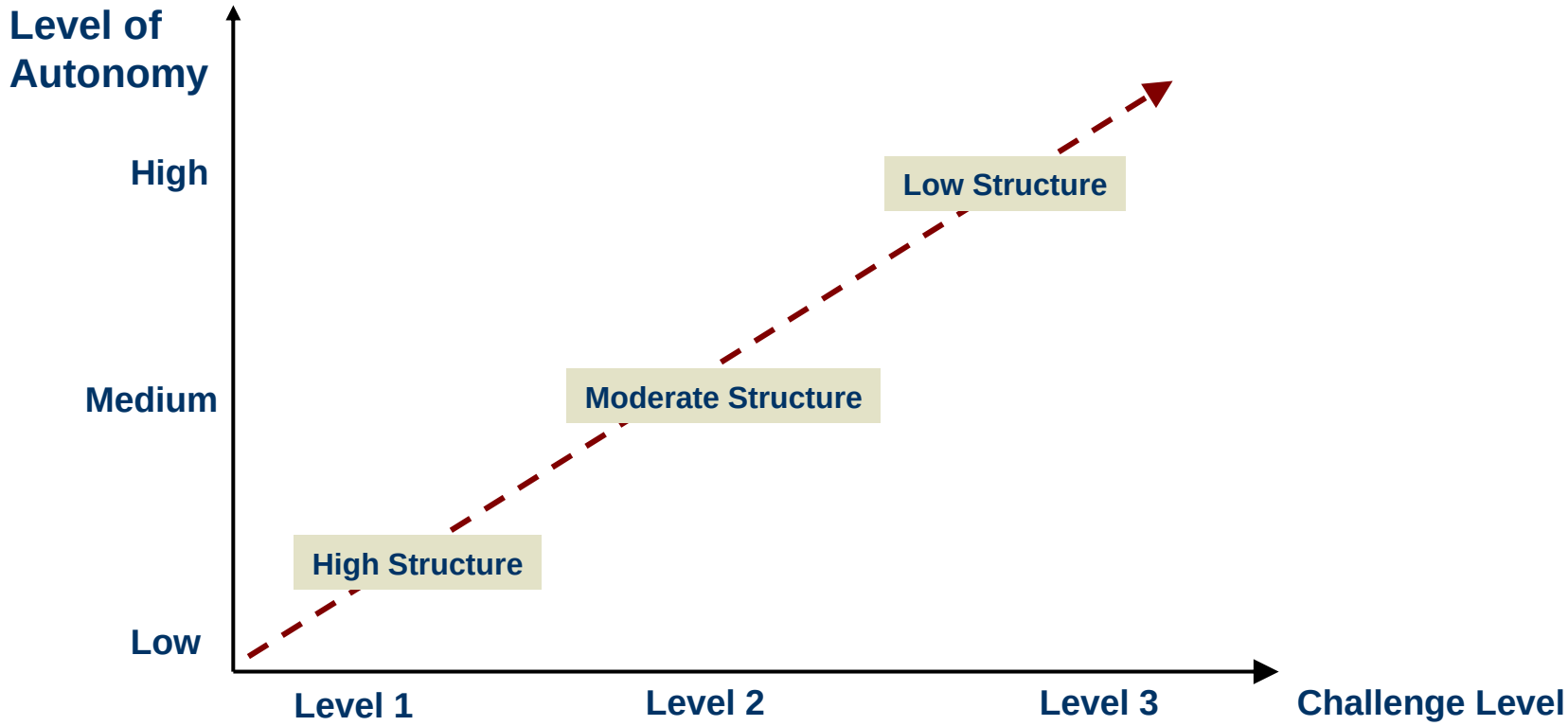
PBL Continuum



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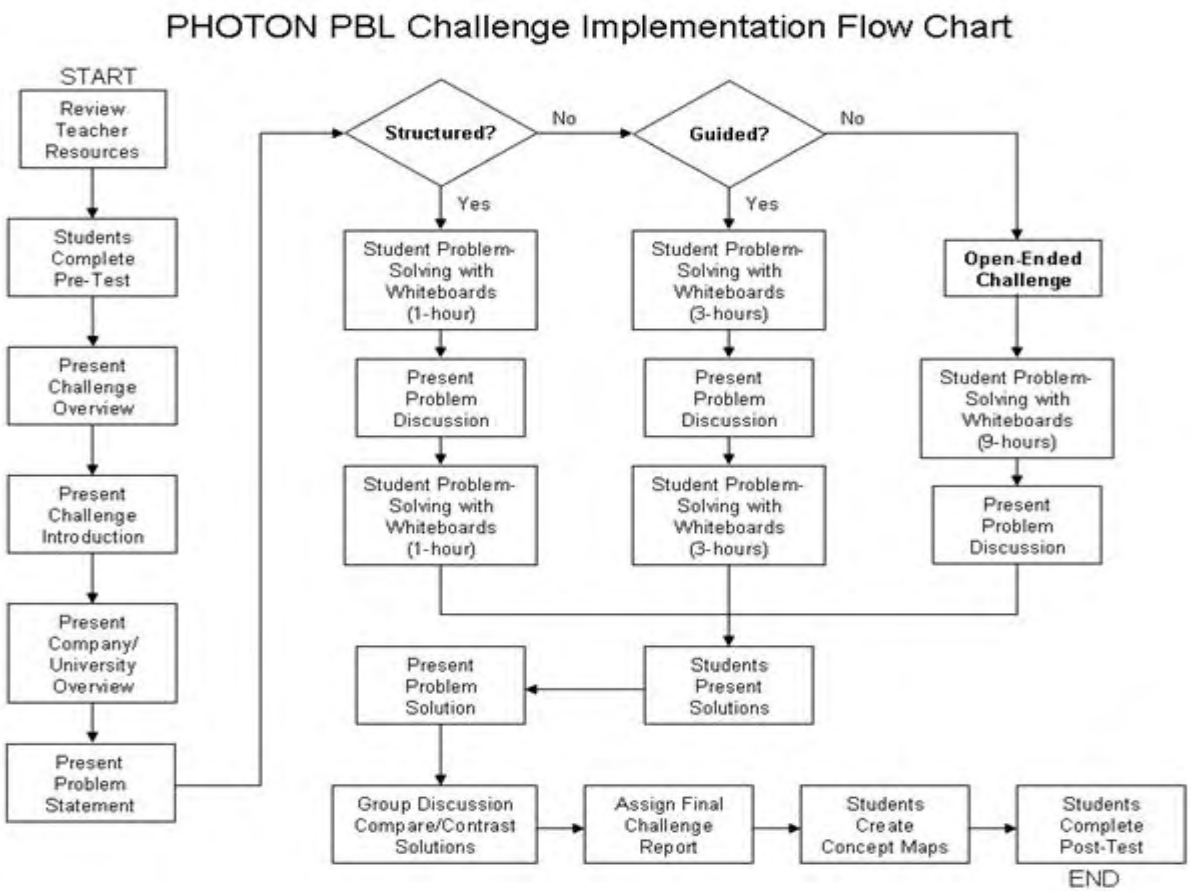

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Photon PBL "Challenges"

Stripping with light, fantastic! - Photomachining needs to develop a process for stripping the coating from 50 micron wire

DNA Microarray Fabrication - Boston University graduate students need to determine the best starting exposure time for a DNA microarry fabricator

High Power Laser Burn-In Test - IPG Photonics needs a way to run 100-hour unattended burn-in tests on a 2-kw laser.

Shining Light on Infant Jaundice - Partners Photodigm, Drexel and SMU ask, "Can technology provide a safe and effective portable home treatment for newborn jaundice?"

Watt's my light? - The package says a 26 watt fluorescent has the same light output as a 100 watt incandescent. Can Cal Poly Pomona students verify this statement?

Of mice and Penn - Can optics provide a non-contact measurement method as part of a UPenn McKay Orthopaedic Research Lab project to study the healing of tendons?

Hiking 911 - Two boys are lost in deep woods in rough terrain. Penn State Electro Optics Center (EOC) needs to recommend the best technology to locate them.

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Photon PBL Challenge Website:

http://vilenski.org/pub

(Passwords Attached)

Photon PBL Conference Papers and Related Resources:

http://photonprojects.org

California State Polytechnic University at Pomona

Watt's my light?

A Problem-Based Learning Challenge

Version 1.2

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New England Board of Higher Education

PHOTONICS

Cal Poly Pomona

Challenge Overview

Description

In this PBL Challenge, you will be part of university student team tasked with measuring the output of light bulbs.

Photonics Principles Reinforced

- Spectral output of light sources
- Optical power measurements
- Radiometry and photometry

STEM Connections

Basic algebra and geometry, energy and power, scientific inquiry

Instructions

Click on "introduction" to view the Introduction to the Cal Poly Pomona Challenge.

introduction

university overview

problem

discussion

solution

credits

Cal Poly Pomona

Introduction

Instructions

Click on video box to view the Challenge Introduction. Click on Additional Resources button for more information. When complete, click on Organization Overview.

introduction

university overview

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additional resources

Cal Poly Pomona

University Overview

Instructions

Click on video box to view the University Overview. Click on "Additional Resources" for more information on Cal Poly Pomona. When complete, click on the "Problem" button to begin the challenge.

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Problem Statement

Instructions

Click on video box to view Cal Poly Pomona problem statement. When complete, click on problem solving graphic in upper right-hand corner for problem solving toolbox or Additional Resources button for more information

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Problem Discussion

Instructions

Click on video box to view Cal Poly Pomona problem discussion. When complete, click on problem solving graphic in upper right-hand corner for problem solving toolbox or "Additional Resources" button for more information.

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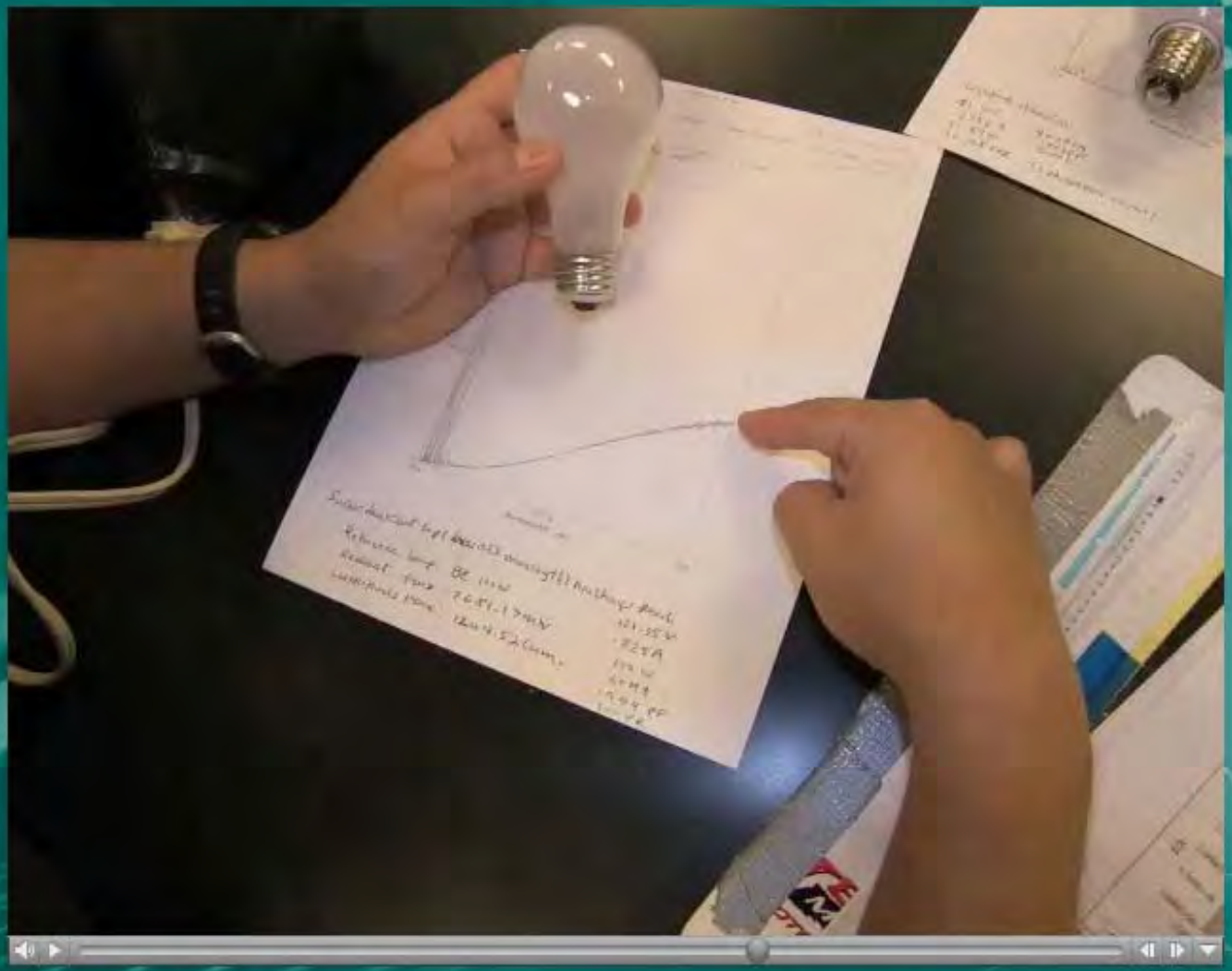
Problem Solution



Instructions

Click on video box to view Cal Poly Pomona problem solution. When complete, click on problem solving graphic in upper right-hand corner for problem solving toolbox or Additional Resources for more information.

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Additional Resources for Solution

Additional Resources

- Script for the solution video
- Solution summary
- Student bulb data
- Results of tests on compact fluorescent bulbs from RPI Lighting Center
- Challenge Reflective Journal
- Labsphere's A Guide to Integrating Sphere Radiometry and Photometry http://www.labsphere.com/tecdocs.aspx

Career & Technical Info

- SPIE: http://www.spie.org
- OSA: http://www.osa.org
- PHOTON2 Project: http://www.nebhe.org/content/view/49/83/

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Problem Solving Toolbox

Click on the graphic to begin the problem solving process.

Problem Solving Toolbox

The White Board - Problem Analysis

What are we trying to accomplish?

What do we know about the problem?	What do I need to learn?	Are there any special conditions that apply?	Any preliminary solution ideas?

Problem Solving Toolbox

The White Board - Self Directed Learning

What are My Learning Goals?

Specifically, what do I need to learn?	What instructional resources will I use?	How will I budget my time?	How will I know when I've achieved my learning objectives?

Problem Solving Toolbox

The White Board - Brainstorming

Let's hear some ideas...

Ideas	Pros	Cons	Ranking	Next Steps

Problem Solving Toolbox

The White Board - Test Solutions

How will I test my solution?

What criteria will I use to determine if my solution is acceptable?	How will I test the solution?	What resources will I need to conduct the test?	What is my timeline for testing?

Cal Poly Pomona

Teacher Resources

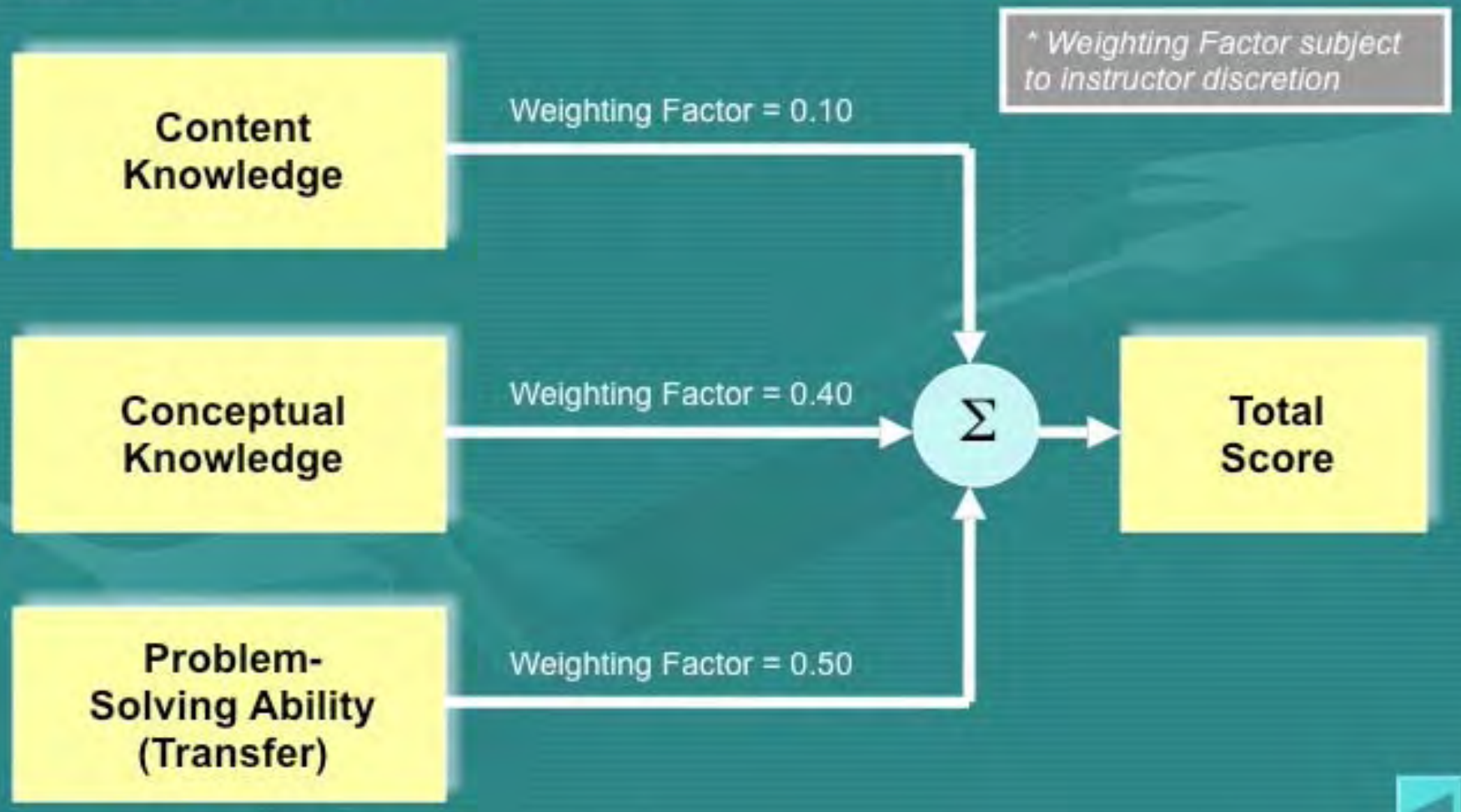
- Technical Background
- Assessment Strategies
- Case Studies
- Standards Alignment

Assessing Student Performance in PBL

(Based on Adaptive Expertise Model[1])

Three - Level Assessment Strategy

*Total score is the **weighted sum** of Content Knowledge, Conceptual Knowledge, and Problem-Solving Ability*



1 - Adapted from Pandy et al. (2004, July). "Assessing Adaptive Expertise in Undergraduate Biomechanics." *Journal of Engineering Education*. American Society of Engineering Education (ASEE)

Assessing Content Knowledge in PBL

Assessed using

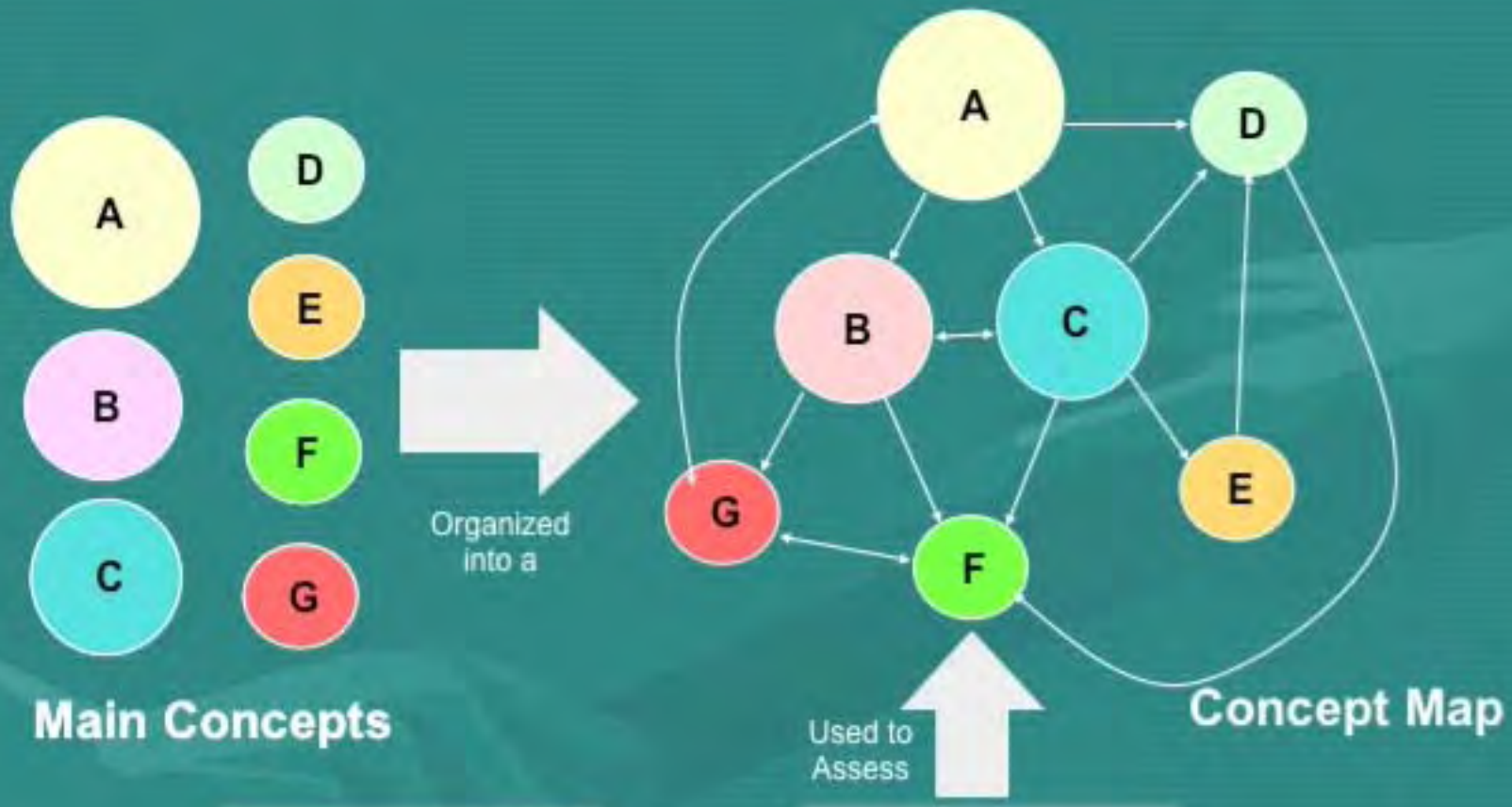
- Exams
- Quizzes
- Homework

Based on

- End of Chapter Questions
- Level I & II Problems
- Laboratory Experiences

(Click here for question bank)

Assessing Conceptual Knowledge in PBL



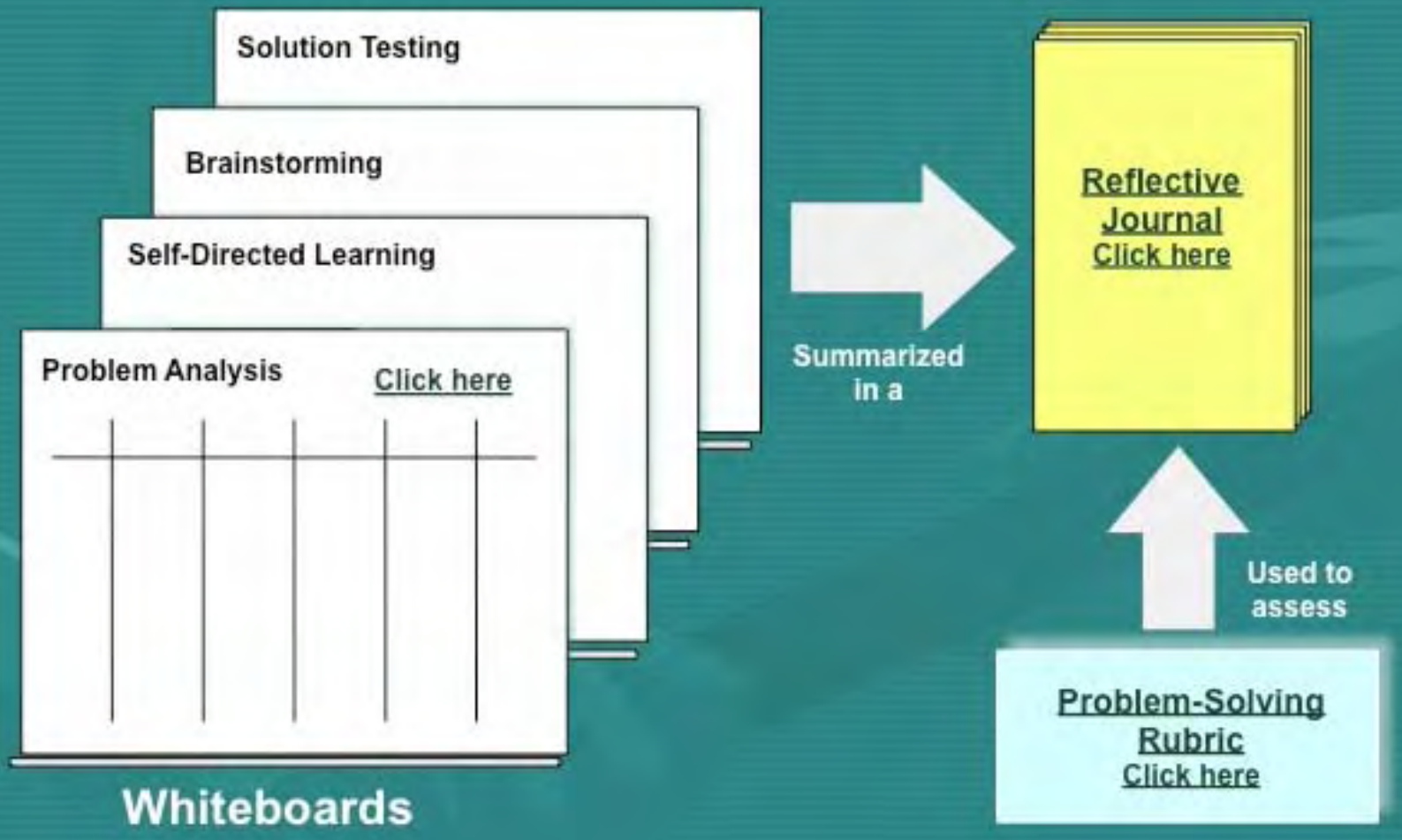
Concept Map for this Challenge

Click here

Concept Map Scoring Rubric

Click here

Assessing Problem-Solving Ability in PBL



Cal Poly Pomona Challenge Credits

California State Polyechnic University at Pomona

National Science Foundation

New England Board of Higher Education

Video and graphic resources

- http://earth2tech.com
  www.sxc.hu
  http://youtube.com/watch?v=juxiql_T5GA
  http://en.wikipedia.org/wiki/Image:RPS-lamps.jpg
  http://www.spectrum-lighting.com/
  http://farm2.static.flickr.com/1068/1074738075_f146872094.jpg
  http://www.sthilda.ca/images/earth.jpg

Voice Actors

- Zbigniew Olczuk, Frank Dubuque, Samantha Bullard, Paul Lariviere, Gregory Doyon, Jr., Matt Donnelly

Photon PBL Team

- Principle Investigators
  - Richard Audet, Ed.D., Roger Williams University
  - Fenna Hanes, New England Board of Higher Education
  - Judy Donnelly, Three Rivers Community College
  - Nicholas Massa, Ph.D., Springfield Technical Community College
- Graphic Design
  - Michele Dischino, Ph.D., Central Connecticut State University
- Web Production
  - Jeff Vilenski, Innovative Computing

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Students Build Integrating Sphere

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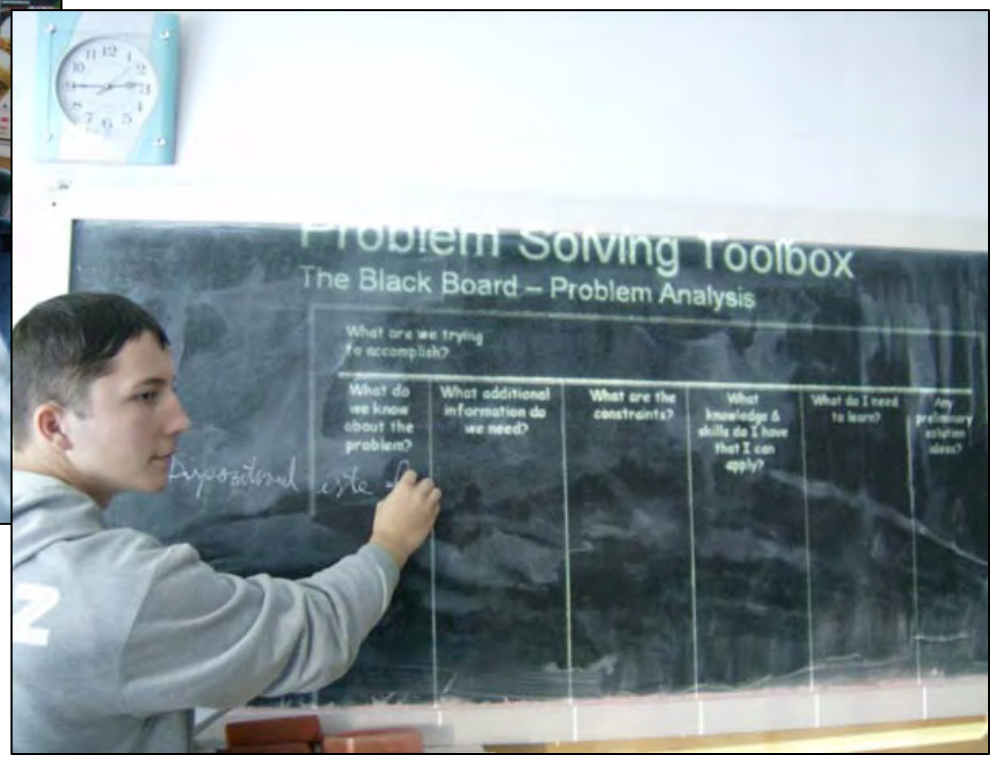

Romanian HS Students using Photon PBL "Whiteboards"

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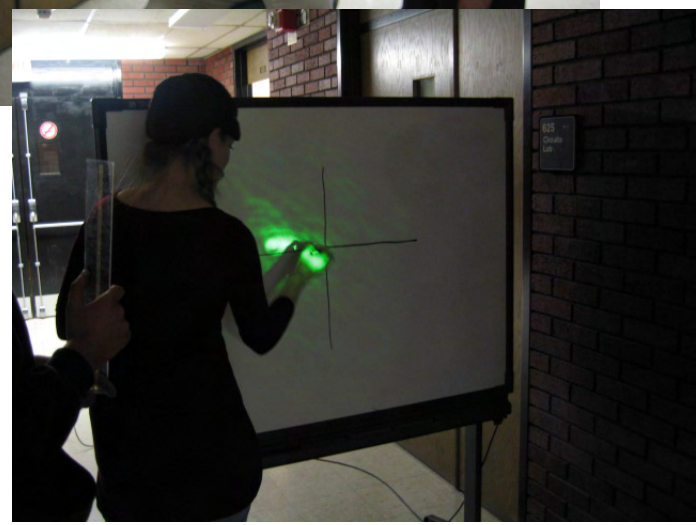
College students using Photon PBL "Whiteboards"



College Students testing problem solution

Concluding Remark

Providing students with an educational experience that most closely emulates the world in which they will apply their knowledge and skills will produce proficient individuals capable of adapting to the ever-changing workplace of the 21st century