GIREP-EPEC-PHEC 2009
A PBL approach to Physics

Derek Raine & Cheryl Hurkett
University of Leicester
14.00-14.40 Look at your pictures. This is your PBL problem
14.40-15.00 PBL – problems and structures
15.00-15.30 Physics by PBL
15.30-16.00 Discussion
What’s the Problem?

14.00-14.40 Look at your pictures. This is your PBL problem
Review: What is PBL

14.40-15.00 PBL – problems and structures
1. What’s the Problem?
2. Supporting a PBL Community
3. What’s your objective? (Deliverables)
4. Making it real
Learning requires...

- Construction of context
- Engagement
- Transformation
PBL promotes:

- Open ended investigation
- Research Environment
- Novel Solutions
- Creativity?

- Can opportunities for creativity promote transformation of content?
Physics by PBL

15.00-15.30 Physics by PBL

15.30-16.00 Discussion
Questions and Discussion

15.30-16.00 Discussion
Obstacles:

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Can we resolve these issue? – Case studies
Our Case Studies

*Communication Science*
Yr 3 IScience module

*Science of the Invisible*
Yr 1 IScience module
Communication Science
Communication Science

- Third year module.
- Attempts to link biological and physical aspects of signals (cell signalling and EM radiation).

Problem Statement:

The set of images have been altered to show aspects of the way in which the eye forms images of the planet Mars. How can they be presented at an exhibition entitled “The Science of Light and Vision”? 
Communication Science

The Deliverables

[01] The pictures are illustrations for a Science of Light and Vision exhibition at a science museum. Write the accompanying detailed textual material for the exhibition for a scientific audience. For guidance, each picture should be accompanied by up to 500 words. The order of the pictures is to be determined by the team. (The numbers are for identification purposes only.)

[02] As museum guides at the press preview for science journalists and editors of scientific journals you will be asked questions about some of the pictures chosen at random. (If the writing of the captions has been subdivided you will not necessarily be asked about the sections you wrote. Thus all students will need to be experts on all of the pictures.)
Communication Science

Learning Objectives
(Abridged)
- Optics
- Cell signalling
- Nerve propagation
- EM radiation (Maxwell’s equation)
- Transmission line

Module Structure
- 4 weeks
- Facilitation sessions
- Expert Sessions
- Core Learning Exercises
Communication Science

Scope for creativity

- Theme of exhibition: what is light?
  Transformation of medium/Preservation of content
  Story of a photon
  Forms of energy
  Light and colour
...

- Freedom to choose significance of each photo
- Freedom to choose the order of the photos
Communication Science

Outcome

• Students were creative in cutting and pasting from the web.
• Focus on medical aspects – not in our Learning Objectives!

Changes

• Facilitation.
• Written guidance.
• Source image.
Science of the Invisible
Science of the Invisible

Problem Statement:

*A for Andromeda* was a made-for-TV Science Fiction serial broadcast in 1961. The basic plot is the discovery of a radio message received from a distant civilisation with coded instructions on how to make a living being. Unfortunately the tapes of all but one of the episodes have been wiped so the coded message has been lost. In order to advertise their remake of the series *TV Remakes Unlimited* decided to publicise the supposed discovery of a “real” coded message received by Jodrell Bank in 1987 which it claimed had been hushed up by the military and government. The code in the original broadcast production was alpha-numeric but it was decided to give the supposedly newly discovered one a hieroglyphic form to make the deciphering more interesting.

You must decide what *each* hieroglyph symbolises and therefore in which order the “message” should be assembled in order to create the life form.
Science of the Invisible

Deliverable

TV Remakes Unlimited intend to publish a companion website as the remake of the *A for Andromeda* series is aired. A section of this site will be devoted to the promotional hieroglyphic “message”; one page will be devoted to each hieroglyph and will be released each time a new episode is aired.

It is your task to compile the scientific information that will be presented on each webpage. The web development team hope that this site will become a useful resource for the fans of the series as well as people who are generally surfing the web. They have asked you to provide approximately 2000 words per hieroglyph, plus 500 words explaining the order of the hieroglyphs; the material should be presented at the same level as an undergraduate text book.

You will NOT be expected to design the site or webpages.
Science of the Invisible

Learning Objectives

- Atomic Structure
- Bonding
- Shapes of Molecules
- Introduction to Organic Chemistry
- Steroisomerism
- Amino acids and proteins
- Fats
- Carbohydrates
- DNA
- Representation versus reality
- Gases
- Solids
- Liquids
- Water and Equilibrium
- Solutions
- Acids and Bases
Science of the Invisible

Scope for creativity

- Association of images
- Order of images
- New images?
Science of the Invisible

Outcome

- Groups ordered hieroglyphs differently – a variation on the theme of concept maps.
- Learning objectives were covered at various levels.
- Web based information was relevant.
- Students apparently enjoyed this aspect of the module.
Discussion:
Matching Problems to Learning Objectives
Session 3

Problem Writing
Planning a PBL Problem

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Problem Summary

Problem Description

Learning Outcomes

Assessment
Session 4: Matching Problems to Deliverables
Deliverables are not problems

An example

Learning objective:

Medical applications of Nanotechnology

Tiny semiconductor crystals reveal cellular activity like never before

Jessica Gorman

Last December, Sanford Simon attended a cell biology meeting where researchers presented picture after picture of cells colorfully highlighted by organic dyes or fluorescent proteins. Speakers also debuted movies—featuring proteins as cellular action heroes. In these little dramas, often lasting only seconds, viewers witnessed the complicated molecular actions underlying cancer, diabetes, and other human diseases. ........

RAINBOW BEADS
Polymer beads embedded with quantum dots fluoresce in five different colors
Problem Statement

A venture capital institution is considering an investment in quantum dot technology for biological applications. The question they have is: is our understanding of the fundamental science mature enough to justify an investment. For example, investment in high temperature superconductivity might be considered risky because the basic science of what makes a material superconducting at liquid nitrogen temperatures is lacking. On the other hand investment in biofuels might be considered less speculative because the basic science is understood and only the technological development remains to be put in place. Thus, it is your task to research the basic science of quantum dots, provide a detailed account of what is known and draw a conclusion as to whether there are outstanding fundamental issues. It is NOT your task to investigate financial, technological, biological or ethical aspects.
Deliverable:

Write a report on the application of nanotechnology to medicine.....

What’s the problem?
The Fossil Record and Evolution
By Tina Calabro

Carnegie scientists prove that Darwin got it right

In the 150 years since the publication of Charles Darwin’s Origin of the Species, scientists have used new data to become even more convinced of Darwin’s observations, yet journalist Jack Kelly of the Pittsburgh Post-Gazette (September 19, 1999) wrote that the fossil record does not support evolution. Nothing could be further removed from the facts.

Millions of fossils, found in well-dated sequences of rocks, show evolution of forms through time and show many transitions among species. The fossil record is unequivocal on the progression of life from simple beginnings to complex organisms. There is a vast body of fossil confirmation of evolution and of natural selection preserved in the world’s great collections.

Is this a solution?
Discussion: How can problems be google-resistant?
Discussion:
What are the deliverables?
Session 2: Supporting a PBL Community
1. Building a Community

- Collaborative Learning
- Generalised PBL Strategy
- Community Building

2. Supporting PBL

- Vidcasts
- Interactive Screen Experiments
- Reuseable Learning objects
Collaborative Learning

Between 1924 and 1997, more than 168 rigorous research studies were conducted comparing the relative efficacy of cooperative, competitive, and individualistic learning on the achievement of individuals eighteen and older.

These studies indicate that cooperative learning promotes higher individual achievement than do competitive approaches or individualistic ones.

College students who would score at the fiftieth percentile level on an individual exam when learning competitively will score in the sixty-ninth percentile when learning cooperatively; students who would score at the fifty-third percentile level when learning individualistically will score in the seventieth percentile when learning cooperatively.

K A. SMITH et al. Pedagogies of Engagement: Classroom-Based Practices
Journal of Engineering Education Jan 2005

Collaborative Learning

Collaborative Learning

- Collaboration builds learning

Why?

- Through a sense of community

Example: Problem-Based Learning
Problem-Based Learning

PBL (problem-based learning) is a student-centred method of teaching in which students learn by investigating real-world problems and, working in groups, seek out the tools necessary to solve them.
Generalised PBL strategy

- **Planning Phase**
  - Agree a brief problem statement
  - List relevant existing knowledge
  - Identify learning outcomes
  - Write a plan

- **Investigation Phase**
  - Enquiry and experiment

- **Analysis Phase**
  - Share and discuss information
  - Apply new information to the problem
  - Evaluate progress
  - Submit work or revisit plan
  - Reflect
Generalised PBL strategy

- Induction
- Planning Phase
- Investigation Phase
- Analysis Phase
- Assessment
Community Building

1. Interactions within groups
2. Interaction with facilitators and staff
3. Balance between group and individual work
4. Interaction between groups
Interactions within groups

- Induction
- Planning Phase
- Investigation Phase
- Analysis Phase
- Assessment

- Group Roles/Rules
- Group Action Plan
- Peer Tutoring
Interaction with facilitators and staff

- Induction
- Planning Phase
- Investigation Phase
- Analysis Phase
- Assessment

- Facilitator
- Subject Expert
- Audience
Group and individual work

- Induction
- Planning Phase
- Investigation Phase
- Analysis Phase
- Assessment

- G & I Learning Outcomes
- Individual
- G & I Deliverables
Interaction between groups

- Induction
- Planning Phase
- Investigation Phase
- Analysis Phase
- Assessment
  - Assessment Design
Authentic Assessment

There is too much data or too many experiments for each group to carry out the whole project alone.

Presentations and reports are required to exchange information.

Water pipes in the desert

Telescope project
Support

- Maths Miniatures
- Interactive Screen Experiments
- Reusable Learning Objects
Discussion

The attention span problem – accessing the web
Discussion

How can we support the facilitator?
Conclusions
Making it real:
1) The Learning-Place Working Project
2) An Internet Journal
CubeSat: Learning Place Working
The University of Leicester's CubeSat project, named PLUME, started in January 2007 and aims to place an active nano-meteoroid dust detector into orbit by mid-2009. This detector will be capable of characterising the near Earth dust environment an order of magnitude better than any previously flown active detector, allowing significant science to be accomplished.

The project team is comprised of approximately 20 undergraduates who both run and manage the project. The mission has the full support of the University of Leicester's Space Research Centre and of Magna Parva. The nanometeoroid detector on PLUME will allow us to analyse dust particles that are smaller than ever before.
Adapting the project for general use

Agency (e.g. Space Research Group)
  - Selection
  - Interviews
  - Internal
  - Appraisal

(Problem)

Employee Roles
  - Reporting
  - Delivery (Solution)

Client (e.g. Astrium)
  - External
  - Evaluation
An Internet Journal
University of Leicester Journals

Journal for Excellence in Teaching and Learning

CETL Journal
JETL A: REPORT Section: Reports on Leicester funded projects
JETL B: ARTICLES: Papers on Educational Research in HE

Physics Special Topics

Journal of Special Topics
VOL 7, NO 1 (2008)

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The Temperature of Jupiter
K S Hill, R Laird & O M Littlejohns

The blackbody temperature of Jupiter is calculated and found to be less than observational evidence suggests. Reasons for the discrepancy are discussed, favouring gravitational collapse during formation.

Stan Cowley (JST Vol 8, 2008) provided infrared temperature measurements of Jupiter’s surface. The observed 143K was suggested to undermine the assumption that Jupiter's surface temperature could be modelled on a blackbody re-emitting the received solar flux. Cowley advocated the presence of additional heat sources which this work has tried to investigate.

We have corroborated Cowley's findings that the observed temperature is more than the theoretical temperature prediction. By first calculating the solar flux at Jupiter’s orbital radius, [1], and then modelling its absorption profile to be circular, the energy that Jupiter receives from the Sun was found. In the following equations, \( L_{\text{Sun}} \) is the luminosity of the Sun, \( r_j \) is the semi-major axis of Jupiter’s orbit, \( R_j \) is the average radius of Jupiter, \( F_j \) is the solar flux at Jupiter’s orbital radius and \( L_j \) is Jupiter’s luminosity.

\[
F_j = \frac{L_{\text{Sun}}}{4\pi r_j^2} \tag{1}
\]

Inserting this into the blackbody law, (Gregory & Zeilik, 1997) [2], a temperature of 124.4 ± 1.9K was calculated.

\[
L_j = 4\pi R_j^2 F_j T^4 \tag{2}
\]

The actual discrepancy between the observed and theoretical luminosities is a factor of 1.8 ± 0.03.

The additional heat sources implied by such a large discrepancy are potentially a complex combination of factors relating to Jupiter's unique situation. Other known planetary internal heat sources do not explain the size of the discrepancy for example, the decay of radioactive elements in the rocky core of the planet, as in terrestrial planets, is too weak a method (Carroll & Ostlie, 1996) and the interior temperatures of Jupiter are far below the 1,000,000K required for thermonuclear fusion, the heat source of stars. This paper proposes that the most dominant source of Jupiter’s excess energy is the slow escape of gravitational energy released during the planet’s formation. ........
END
PLANNING A PBL PROBLEM

PROBLEM SUMMARY

Subject Area
Topic
Year/Level
Class Size
Group Size
Time to Run

PROBLEM DESCRIPTION

LEARNING OUTCOMES

ASSESSMENT
Example

(a) A coil of length 10 cm, radius 1.5 cm has 1000 windings. What is its inductance?

(b) Calculate the capacitances for two tuned LC circuits, frequencies 160 kHz and 500 kHz using the inductor in part (a).

(c) A parallel plate capacitor has plate area 10 cm$^2$. What plate separations are required to obtain the capacitances in part (b)?

(d) What is the Q-value of a circuit with $L = 10 \text{mH}$, $C = 1 \mu\text{F}$ and $R = k\Omega$.

(e) What resistance placed in series will be required to ensure the two signals are separated in the tuned circuits of part (b)?
The sugar is well mixed into the liquid cocoa using our Melangeur. Both the sugar and cocoa solid particles are ground down smaller and smaller while more and more fat is released from the cocoa. The sugar/cocoa mixture becomes smoother and remains a thick liquid known as chocolate "paste," now ready for the refining and conching process to follow.
Sugar Granules

From the documentation it is clear that the control of the size of sugar particles is important in chocolate manufacture. The Granada Chocolate Company is a small company in the Caribbean which might benefit from semi-automating the grinding process. To do this is it would be necessary to check the granularity of the sugar being introduced to the mix. It has been suggested by your research department that a simple way to check the granule size is to measure the bulk dielectric constant of the granulated sugar.

Your task is therefore to investigate if the granularity of sugar can be checked by determining its dielectric constant.
Refraction is the bending of the path of a light wave as it passes from one material to another material. The refraction occurs at the boundary and is caused by a change in the speed of the light wave upon crossing the boundary. The tendency of a ray of light to bend one direction or another is dependent upon whether the light wave speeds up or slows down upon crossing the boundary. Like any wave, the speed of a light wave is dependent upon the properties of the medium. In the case of an electromagnetic wave, the speed of the wave depends upon the optical density of that material. The more optically dense a material is, the slower that a wave will move through it.

One indicator of the optical density of a material is the index of refraction value of the material. Index of refraction values are numerical index values, which are expressed relative to the speed of light in a vacuum. The index of refraction value of a material is a number which indicates the number of times slower that a light wave would be in that material than it is in a vacuum. A vacuum is given an n value of 1.0000.

Patent Application Template

The Leicester Physics Patent Office can accept applications in the following format only.

Names of companies: __________________________

Date: __________________________

What is the purpose of the proposed device? (50 words max)

What is the basic principle behind the device? (100 words max)

Section 1: Project Details

Company: Scrumptious Confectioners
Project: Temperature Alarm
Start date: 8 March 2004
Finish date: 15 March 2004