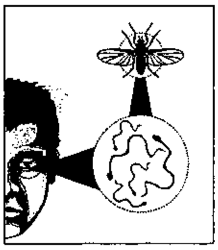
BEYOND PHYSICS AS FACT
PREPARING RICH CURRICULUM UNITS

UNIT 1: LIGHT & SIGHT IN FOCUS

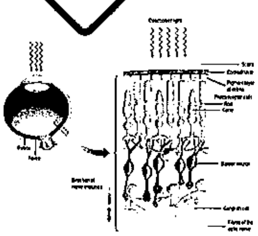
CONNECTEDNESS

HEALTH & SOCIAL EDUCATION
Responsible action about health and social issues



What are we doing to reduce visual impairment and blindness in the world?

RESULTS



KEY IDEAS
The way people lose their sight and possible treatments

- How light travels
- Mirrors & lenses
- emr and colour
- Eye.

UNIT 6: TRANSFORMATION BY STEAM

HUMAN INGENUITY
Creating solutions & their impact on society & environments.

CONNECTEDNESS

How have scientific inventions led to major changes in society?

Internet search 16th century mining

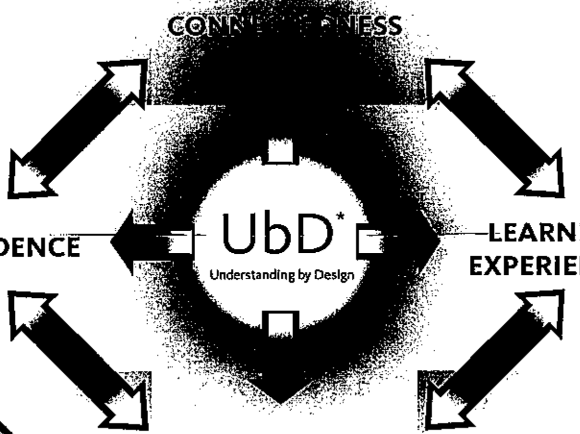
LEARNING EXPERIENCES

Watt on stage
Produce a theatrical piece that demonstrates the innovations James Watt made to the Newcomen steam engine.

CONNECTEDNESS

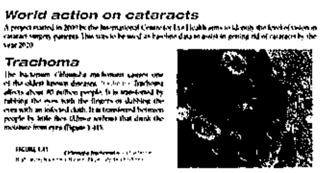
AREA OF INTERACTION (IBMYP)

Social & personal meaning



Assessment: understanding & proficiency

Knowledge: facts, concepts, principles Skills: processes, procedures, strategies.

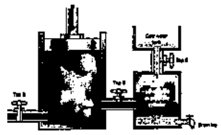


CONNECTEDNESS

What should students know, understand & be able to do?

KEY IDEAS
The development of the steam engine, which led to many changes in society

- Energy
- Heating & cooling
- Temperature
- Pressure.



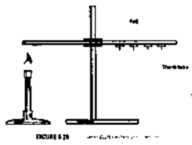
RESULTS

SUMMATIVE ASSESSMENT TASK
Organise World Sight Day event

- Improve conditions
- Show how scientific knowledge is used.

EVIDENCE

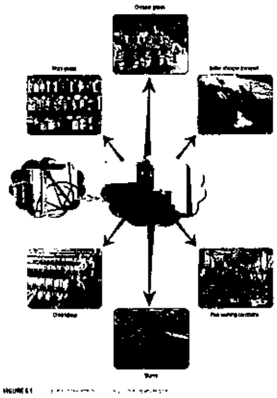
KEY IDEAS (IBMYP)

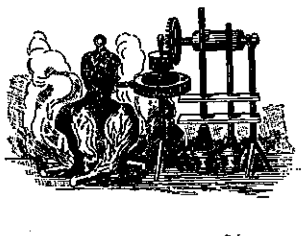


Heat conduction

Energy transfer and temperature change

Practical activities
- Eye dissection
- Mixing colours.





Turbines

IBMYP Science Assessment

- A One World: interdependence of science and society.
- B Communication: accurate information in a variety of genres.
- C Knowledge and understanding: use of ideas in familiar and unfamiliar situations.
- D Scientific inquiry: design and conduct investigations.
- E Processing data: sift, sort and report data in a variety of forms.
- F Attitudes in science: safety, respect, collaboration.

EVIDENCE

References
Wiggins, Grant and Jay McTighe (2006), *Understanding by Design*, Pearson, NJ. and (2004) *Understanding by Design: Professional Development Workbook*, Association for Supervision and Curriculum Development, Virginia, USA.
International Baccalaureate Organisation (2008), *Middle Years Program MYP: From principles into practice*, Cardiff, UK.

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References
Armstrong, Rick, Neil Champion and others (2010). *Science for the International Student 4/5: Physics*, Nelson Cengage Learning, Melbourne.
Unit 1, Light and sight in focus, 1-38, and Unit 6, Transformation by steam, 177-212

Entry Points for the Design Process

Important topic or content

- What Big Ideas either underlie this topic or emerge from studying it?
- Why is it so important?

Established goals or content standards

- What Big Ideas are embedded in this goal?
- What will students need to understand to *really* learn this?

An important skill or process

- What will this skill enable students to do?
- What will students need to understand to effectively apply this skill?

Stage 1—Desired Results

Stage 2—Assessment Evidence

Stage 3—Learning Plan

- What will students need to understand to perform well on this test?
- What other evidence of learning is needed?

A significant test

- Exactly *why* are we having students read this text or use this resource?
- What Big Ideas do we want students to understand as a result?

A key text or resource

- What Big Ideas will students come to understand as a result of this activity or unit?
- What evidence of understanding is needed?

A favorite activity or familiar unit

1-Page Template with Questions

Stage 1—Desired Results

Established Goals: G

- What relevant goals (e.g., content standards, course or program objectives, learning outcomes) will this design address?

Understandings: U

Students will understand that . . .

- What are the big ideas?
- What specific understandings about them are desired?
- What misunderstandings are predictable?

Essential Questions: Q

- What provocative questions will foster inquiry, understanding, and transfer of learning?

Students will know . . . K

Students will be able to . . . S

- What key knowledge and skills will students acquire as a result of this unit?
- What should they eventually be able to do as a result of such knowledge and skill?

Stage 2—Assessment Evidence

Performance Tasks: T

- Through what authentic performance tasks will students demonstrate the desired understandings?
- By what criteria will performances of understanding be judged?

Other Evidence: OE

- Through what other evidence (e.g., quizzes, tests, academic prompts, observations, homework, journals) will students demonstrate achievement of the desired results?
- How will students reflect upon and self-assess their learning?

Stage 3—Learning Plan

Learning Activities: L

What learning experiences and instruction will enable students to achieve the desired results? How will the design

W = Help the students know Where the unit is going and What is expected? Help the teacher know Where the students are coming from (prior knowledge, interests)?
H = Hook all students and Hold their interest?
E = Equip students, help them Experience the key ideas and Explore the issues?
R = Provide opportunities to Rethink and Revise their understandings and work?
E = Allow students to Evaluate their work and its implications?
T = Be Tailored (personalized) to the different needs, interests, and abilities of learners?
O = Be Organized to maximize initial and sustained engagement as well as effective learning?

AREA OF STUDY 2

How can thermal effects be explained?

Concepts related to energy can span both large and small scales. In this area of study students investigate the thermodynamic principles related to heating processes, including concepts of temperature, energy and work. Thermal systems in Earth and human activities have environmental impacts in terms of the emission of greenhouse gases. Students explore the impacts and efficiencies of energy production in order to consider the debate about global warming and the enhanced greenhouse effect.

Students investigate principles of thermodynamics and their environmental effects through one or more of three options: the car; the home; and/or Earth.

Option 1: Thermodynamics and the car

An invention that has had a significant impact on both humans and the environment is the internal combustion engine. Thermodynamics principles may be used to explore these impacts.

- How do internal combustion engines work?
- What impact do internal combustion engines have on the environment?
- How does a four stroke internal combustion engine work?
- How does the electric motor compare with the internal combustion engine?
- Can thermodynamic principles related to the use of the internal combustion engine allow for investigation and evidence collection to inform the debate about global warming and the enhanced greenhouse effect?

Option 2: Thermodynamics and the home

The heating and cooling of homes in Australia represents a significant proportion of national energy use. Thermodynamics principles may be used to explore how increased energy efficiency may be achieved.

- Is domestic heating efficient?
- Can homes be built that don't need heating at all?
- How do the operation and efficiency of heat pumps, resistive heaters, air conditioners, evaporative coolers, solar hot water systems and electrical resistive hot water systems compare?
- How is an assessment of the energy ratings of home appliances and fittings including insulation, double glazing and window size, determined?
- Can thermodynamic principles related to the use of home appliances and fittings allow for investigation and evidence collection to inform the debate about global warming and the enhanced greenhouse effect?

Option 3: Thermodynamics and Earth

Thermal systems in Earth may be explored by the consideration of thermodynamics principles.

- How can thermodynamic principles assist in the analysis, interpretation and explanation of the changes in the thermal energy of the surface of Earth and Earth's atmosphere?
- The heat engine is a system that uses a difference in temperature to do work and ideally can be describe by four stages. Earth has two heat engines, the atmosphere and the mantle, which can be modelled using the Carnot cycle. What effect do these two cycles have on global systems?
- The maximum theoretical efficiency decreases with increasing temperatures. Does this have significant implications as global temperatures rise?
- Can thermodynamic principles related to thermal systems in Earth allow for investigation and evidence collection to inform the debate about global warming and the enhanced greenhouse effect?

Outcome 2

On completion of this unit the student should be able to apply thermodynamic principles to analyse, interpret and explain changes in thermal energy in contexts including the car, the home and/or Earth.

To achieve this outcome the student will draw on key knowledge outlined below and the related key skills on pages 9 and 10.

Key knowledge

Thermodynamics principles

- apply the First Law of Thermodynamics in simple situations
- define the Zeroth Law of Thermodynamics as two bodies in contact with each other coming to a thermal equilibrium
- convert temperature from degrees Celsius to kelvin
- define temperature as linked directly to the average kinetic energy of the atoms and molecules within a system
- calculate the kinetic energy of particles within a system using: $E_k = \frac{1}{2}mv^2$
- understand thermal energy of a monatomic gas in terms of the average kinetic energy of its particles: $U = \frac{1}{2}Nm\overline{v}^2 = \frac{3}{2}NkT$
- identify absolute zero temperature by extrapolating from a graph of volume versus temperature for an ideal gas
- describe heat transfers between and within systems as conduction, convection or radiation
- analyse the energy required to raise the temperature of a substance: $Q = mc\Delta T$
- analyse the energy required to change the state of a substance: $Q = mL$
- explain why cooling results from evaporation using a simple kinetic energy model.

Thermodynamics and global warming

- identify regions of the electromagnetic spectrum as radio, microwave, infrared, visible, ultraviolet, x-ray and gamma waves
- describe electromagnetic radiation emitted from the sun as mainly ultraviolet, visible and infrared
- calculate the peak wavelength of the re-radiated electromagnetic radiation from Earth using Wien's Law: $\lambda_{max}T = \text{constant}$
- explain how some gases in the atmosphere (including methane, water and carbon dioxide) absorb and re-emit infrared radiation
- model the greenhouse effect as the flow and retention of thermal energy from the sun, Earth's surface and Earth's atmosphere.
- evaluate the influence of human activity in contributions to the enhanced greenhouse effect, including affecting surface materials and the balance of gases in the atmosphere.

1-Page Template

Stage 1—Desired Results	
Established Goals: G	
Understandings: U *Students will understand that . . .*	**Essential Questions:** Q
Students will know . . . K	*Students will be able to . . .* S
Stage 2—Assessment Evidence	
Performance Tasks: T	**Other Evidence:** OE
Stage 3—Learning Plan	
Learning Activities: L	

Unit 2: How do observations shape knowledge?

AREA OF STUDY 1

How can motion be described?

In this unit, students observe motion and explore the effects of balanced and unbalanced forces on motion. They analyse motion using concepts of energy, including energy transfers and transformations, and apply mathematical models during experimental investigations of motion. The motion of an object can be described and analysed using specific terminology as well as graphically, numerically and algebraically.

In this area of study students will model how the mass of finite objects can be considered to be at a point called the centre of mass.

Outcome 1

On completion of this unit the student should be able to investigate, analyse and mathematically model the motion of particles and bodies.

Key knowledge

Concepts used to model motion

- identify parameters of motion as vectors or scalars
- analyse graphically, numerically and algebraically, straight-line motion under constant acceleration: $v = u + at$, $v^2 = u^2 + 2as$, $s = \frac{1}{2}(u+v)t$, $s = ut + \frac{1}{2}at^2$, $s = vt - \frac{1}{2}at^2$
- graphically analyse non-uniform motion in a straight line
- apply concepts of momentum to linear motion: $p = mv$.

Forces and motion

- explain changes in momentum as being caused by a net force: $F = \frac{\Delta p}{\Delta t}$
- model the force due to gravity, F_g, as the force of gravity acting at the centre of mass of a body, $F_g = mg$, where g is the gravitational field strength which is 9.8 N kg^{-1} near the surface of Earth
- model forces as vectors acting at the point of application (with magnitude and direction), labelling these forces using the convention 'force by A on B' or F_{AB}
- apply Newton's three laws of motion to a body on which forces act: $a = \frac{F_{net}}{m}$, $F_{AB} = -F_{BA}$
- apply the vector model of forces, including vector addition and components of forces, to readily observable forces including the force due to gravity, friction and reaction forces
- calculate torque: $\tau = Fr_{\perp}$
- analyse translational forces and torques in simple structures that are in rotational equilibrium.

Energy and motion

- apply the concept of work done by a constant force using
  - work done = constant force × distance moved in direction of force: $W = Fs$
  - work done = area under force-distance graph
- analyse Hooke's Law for an ideal spring theoretically and practically: $F = -k\Delta x$
- analyse and model energy transfers and transformations using energy conservation
  - changes in gravitational potential energy near Earth's surface: $E_g = mg\Delta h$, and kinetic energy: $E_k = \frac{1}{2}mv^2$
  - potential energy in ideal springs: $E_s = \frac{1}{2}k\Delta x^2$, and kinetic energy: $E_k = \frac{1}{2}mv^2$
- analyse rate of energy transfer using power: $P = \frac{E}{t}$
- calculate the efficiency of an energy transfer system: $\eta = \frac{\text{useful energy out}}{\text{total energy in}}$
- analyse impulse (momentum transfer) in an isolated system (for elastic collisions between objects moving in a straight line): $I = \Delta p$.

1-Page Template

Stage 1—Desired Results	
Established Goals: G	
Understandings: U *Students will understand that . . .*	**Essential Questions:** Q
Students will know . . . K	*Students will be able to . . .* S
Stage 2—Assessment Evidence	
Performance Tasks: T	**Other Evidence:** OE
Stage 3—Learning Plan	
Learning Activities: L	

Australian Institute of Physics 19th National Congress: Session 109.00

Beyond physics as fact: preparing rich curriculum units

Neil Champion

Williamstown High School

The poster shows the backwards design processes [1] involved in developing two units for the International Baccalaureate Middle Years Program (IBMYP) [2]. Backwards design focuses attention on rich, engaging and authentic summative assessment tasks. These assist in driving the (non-linear) selection of content, activities, practical work, research projects and formative assessment tasks, as well as more limited summative tasks.

In IBMYP Science there are seven Areas of interaction, the two presented in the poster being Health and social education, which teaches optics through vision and vision impairments and Human ingenuity, which uses a social history approach to thermodynamics. Each unit has a main question and a complex summative assessment task presented at the start.

Features of the units include a broad question with a complex summative assessment task that serve to drive the unit along. These are supported by teaching and learning activities that promote cooperative learning, deep understanding, practical skills, qualitative and quantitative problem-solving and practical inquiry activities that require student initiative. Students are encouraged to reflect on their own learning and to pursue links between the unit's Area of interaction and other big picture Areas of interaction. Opportunities to sift and sort information from the Internet are included.

The effects of science and technology on society are integral to the units so that students are not subjected to a dusty, positivist view of science devoid of moral compass.

*   *   *   *   *   *   *   *   *   *   *   *   *

The poster's four-sided central icon shows the three stages of backward design (Wiggins and McTighe 2006:17-23) and the IBMYP requirement that science students be connected to the world through different Areas of interaction (IBO 2008: 20-33). Subsidiary icons take their cue from the central icon. They are used to link some features of the units to the overall design process.

Understanding by Design (UbD)

The three stages of backward design comprise:

1. **Identify desired results.**
   The emphasis is on the "enduring" understandings that underpin the unit. Prevailing standards and a desire to engage students in worthwhile understandings help drive decisions that prioritize those concepts, learnings and values that students should know, understand, and be able to do.
2. **Determine acceptable evidence.**
   Data that will demonstrate understandings and proficiency is explicitly considered at the outset, not as a final thought somewhere near the end of the unit. As the set of enduring understandings is decided and prioritized, so the question of what will constitute appropriate assessment evidence, and how students will be engaged in the production of authentic responses takes shape.
3. **Plan learning experiences and instruction.**
   Once the desired results and assessment data tools are clarified, the "big ideas" can be broken down into the required knowledge and skills, into facts, concepts and principles on the one hand, and processes, procedures and strategies on the other.

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"Backward design may be thought of ... as purposeful task analysis: Given a worthy task to be accomplished, how do we best get everyone equipped?"

Backward design is not a linear process. Teachers do not come to design cold. They already know much about the knowledge and skills of the area of study they wish to plan. They have ideas about appropriate assessment tasks. They are cognizant of the external standards that students are expected to attain. Nevertheless, this process is quite different from two kinds of aimlessness that beset traditional processes: activity-oriented design and coverage. Activity-oriented design focuses on things for students to do without asking whether these lead to worthwhile construction of meaning. Coverage design insists that every fact that needs to be learned is "in the course" without asking if deep learning can be achieved.

International Baccalaureate Middle Years Program

The fourth design pillar in the central icon is *Connectedness*. It points to units based on two of the five IBMYP Areas of interaction.

Areas of interaction

1. **Health and social education.**
   Students learn about pressing health and social issues, the role of science in their solution, and develop skills to take ethical action.
2. **Human ingenuity.**
   Students learn about the way humans have influenced the world, for good and bad, by finding solutions and causing problems.

The other IBMYP Areas of interaction are: Approaches to learning (see session 106.00), Community and service, and Environments.

Each unit comprises a broad question (UbD: Enduring understanding - Results) and a complex summative assessment task (UbD: Results; UbD: Assessment – Evidence). These are shown at the top of the poster for each unit.

There are other activities, such as Eye Dissection or Heat Transfer that contribute to the IBMYP sevenfold assessment regime (bottom left of poster). Their inclusion highlights the non-linearity of the design process, since these are, simultaneously, purposeful activities (UbD Learning experiences) and assessment tasks (UbD Evidence).

Key Ideas (UbD: Results) are shown in two stages: a main idea and particular knowledge and skills. Learning activities within the units include practical activities, theatrical pieces and Internet research.

Units are rounded out, though this is not shown on the poster, by problem sets and self-reflective activities such as mind maps (at start and re-visited during unit), role plays and a focus on attributes of learners: inquirers, thinkers, communicators, organized and collaborative.

REFERENCES

[1] Wiggins, Grant and Jay McTighe (2006), Understanding by Design, Pearson, NJ, and (2004) Understanding by Design: Professional Development Workbook, Association for Supervision and Curriculum Development, Virginia, U.S.A.

[3] International Baccalaureate Organisation (2008), Middle Years Program MYP: From Principles into Practice, Cardiff, U.K.

[4] Armstrong, Rick, Neil Champion and others (2010), Science for the International Student 4/5: Physics, Nelson Cengage Learning, Melbourne, Unit 1, Light and sight in focus, 1-38, and Unit 6, Transformation by steam, 177-212.

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