Do interventions using threshold concepts assist learning in biology?

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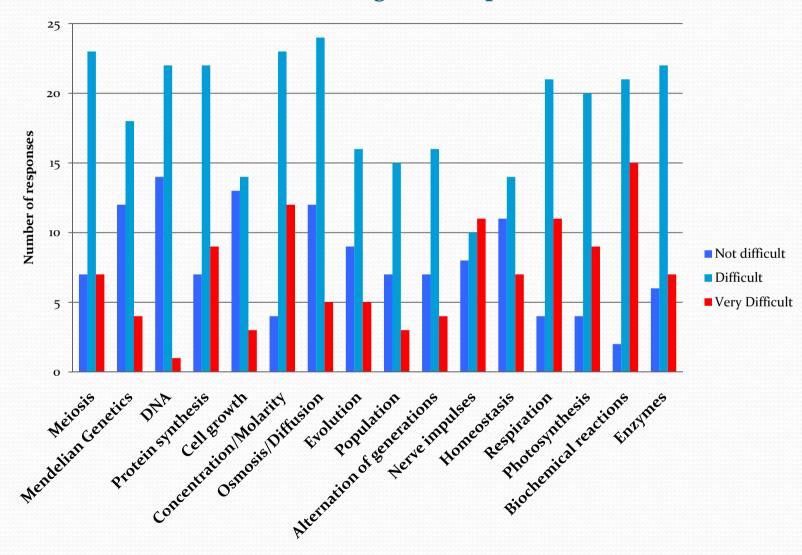
Thresholds

- Conceptual gateway
- Three critical descriptors are used to identify threshold concepts: transformative, irreversible and integrative.
- ALTC-funded project to investigate biology thresholds
- Surveys:
 - Initially, staff surveys and interviews to identify biological threshold concepts
 - Student interviews are ongoing at 3 universities
- Workshops
- First intervention at UNSW

Responses of experienced academics to the question "What are threshold concepts in Biology?"

Concept	Number of Responses = Level of Difficulty
Meiosis and Genetics	3
Evolution	3
Photosynthesis	2
Respiration	1
Enzymes	1
Osmosis/concentrations	1
Protein synthesis	1
Probability	1
Homeostasis	2
Dynamics and Change	1
Surface Area to Volume	2
Scale	3
Energy	1

Ranking of concepts



The relationship between troublesome, conceptually difficult concepts, basic and fundamental key concepts, discipline concepts and threshold concepts and threshold epistemes (Ross et al, 2009). Troublesome Pre-basic **Basic Concepts** Discipline Threshold Web of Threshold Knowledge Concepts Concepts Concepts Concepts Surface area to Volume Plant, Animal, Living, Pigmentation. Light/Dark cycles, Cellular Photolysis, Electron Chloroplast/ Chlorophyll, ratio, Thinking at Breathing Gases/Air Metabolic Transport Chain, Energy Mitochondria. submicroscopic & Conversion (light-chemical), **Processes** Membranes, Cells. subcellular level. Scale. Energy Carbon fixation (gas-solid). Gases O₂/CO₂, Energy transformations, Sugar-ATP transformation Wavelength, Enzymes Thermodynamics Families, Generation. Surface Area to Inheritance, Breeding, Genetics Volume Ratio Discrete characteristics. Farming, Sex, Growth Alleles - Genes. Variation DNA. Chromosomes. Variation, Discrete Individuals- Populations. Gametes, Stage names Units, reproductive **Probability** DNA duplication & (e.g. centromere), replication, Gene expression success, randomness, **Proportional Evolution** Cellular repair, Scale – temporal and reasoning Reproductive processes, spatial Farming, Breeding Location of genes and Predictive Variation of physical units of inheritance Reasoning characteristics, Best Reproductive success. Hypotheses suited/adapted to Adaptation, Physical Variation, Probability, reproduce, Time Scale - temporal **Testing** inheritance of **Protein Synthesis** No pre-basic characteristics Randomness Duplicated Dynamic, Duplication, Subcellular/ chromosomes, transport Thinking at DNA, mRNA, tRNA, of information, Macroscopic submicroscopic & movement, Linkage rRNA, amino acids, Scale -temporal subcellular level between DNA, mRNA ribosomes, nucleus, and spatial and tRNA cytoplasm, enzymes **Ecology** Concentration Rigour, reliability, Interaction of humans Experimental Design, Equilibrium models, probability, Populations, communities, with their environment Niche Succession ecosystems, prey/predator. Randomness, mean, SD, SE, Sampling, Variation, Hypothetico-deductive Physicochemical factors Life tables reasoning, null hypothesis testing Homeostasis Balance Regulation of metabolic Maintenance, Equilibrium factors Hormones Acquisition of Language; Dimensionality; Complexity; Dynamism

Why Scale?

- Biological world extends from the submicroscopic (molecular) to the macroscopic (ecology) with interactions at various levels of scale
- Scale is a component of many "difficult concepts" or "troublesome knowledge":
 - Photosynthesis
 - Metabolism
 - Enzymes and substrate recognition
 - Transcription/translation
 - Cellular transport
 - Micro-environments
 - Osmosis/diffusion

Scale intervention

- Initial intervention at UNSW with 700 first year biology students
- Placed into 2 groups intervention and control
- Threshold investigated: scale
- Outline
 - Pre-course survey
 - 2. Intervention 1
 - 3. Intervention 2
 - 4. Survey
 - 5. Assessment

Pre-course survey

- Provided with image of plant cell. Asked to:
 - Identify cell type and organelles
 - Which organelles would you be able to see under a light microscope?
- Results (247 respondents):
 - 70% correctly identified cell type
 - Of 36 who identified as animal cell, 33 then correctly identified plant cell features
 - Under the microscope: nucleus (38%), cell wall (16%), chloroplast (12%), vacuole (13%)

Intervention 1

Intervention group

Directed to Cells Alive website

- Images of different cell types sitting on the head of a pin
- With this as stimulus, asked to reflect on size of organisms, organelles and molecules
- Also, movement of molecules within and around cells

Control Group

Directed to same website but different section

- Told to use animation to visualize the differences between plant and animal cells.
- Then use it to identify key intracellular components of the different cell types.

Intervention 2

WEHI transcription/translation animation

(http://www.youtube.com/watch?v=4PKjF7OumYo)

- Scale issues from this resource
 - Temporal (fast!)
 - Concentration of molecules
 - Substrate recognition (flexibility/dynamics of molecules, 3D-shape)
 - Functional (protein) domains
 - Relative size of nucleic acids versus protein

Intervention 2

Intervention Group

While you are watching the video, consider the following in relation to the different processes that are occurring:

- Where do these processes happen?
- How fast are these processes?
- Do you think transport of the components to the required locations is important?
- What is the size of the region (or organelle) where this process is happening in relation to the size of the cell? (i.e. Is it much bigger or smaller?)
- How often do these processes occur in a cell?

Control Group

While you are watching the video, consider the following in relation to the different processes that are occurring:

- What is happening?
- What are the components, substrates and enzymes?
- What is a template?
- What are the products of the process?

Post Intervention 2 Survey

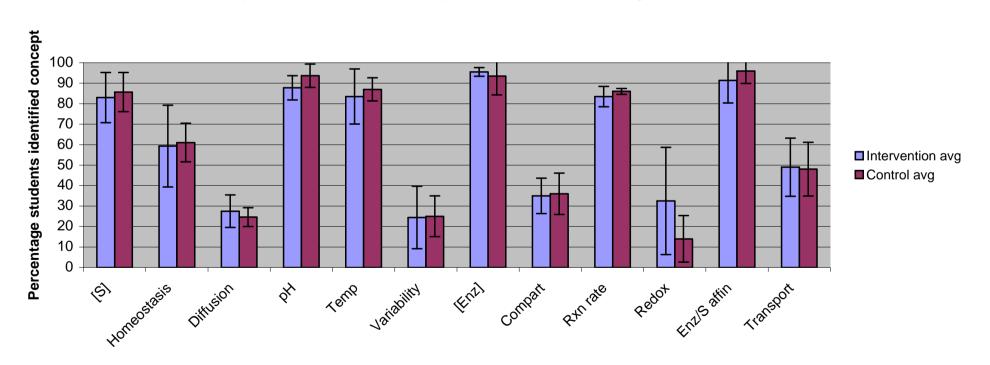
In a practical focusing on the variables that affect enzyme function and kinetics, students (intervention and control groups) were asked to fill out a survey:

In considering the functioning of DNA polymerase:

- 1. Which of the following concepts would you include?
- 2. Which of these concepts do you consider to be difficult to understand?
- compartmentalisation
- ES complex formation
- reaction rate
- enzyme/substrate affinity
- structure/function
- substrate concentration
- enzyme concentration
- effect of temperature
- effect of pH

Comparison of control and intervention groups by concept

Concepts identified as important to DNA Polymerase function

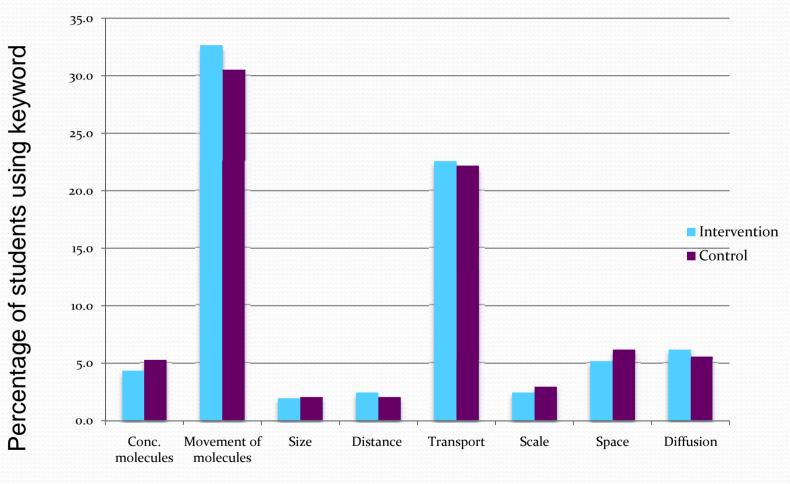


Assessment

In the final exam, students were asked to answer an essay question on respiration and photosynthesis including the following:

... the movement of molecules through the cell and across the membranes that are involved.

Comparison of control and intervention groups by keyword



Keywords

Conclusions

- No clear difference between the intervention and the control groups
 - Intervention too subtle?
 - Logistics of running an intervention on only some students in a course
 - Threshold may have been too peripheral to the course for us to be able to demonstrate a quantitative difference
 - Short-term assessment on what might be a long-term effect
- How do you measure or assess thresholds?

Future directions

- Use entire class and compare with previous year's cohort (have a base-line)
- Incorporate a longitudinal review of this and future cohorts
- Additional and more focused questions
- Other thresholds being examined include:
 - Hypothesis formulation and testing
 - Language
 - Energy transfer
- Need to consider how we communicate ideas and concepts in biology (scale is integral to learning and how we teach biology)