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?”

<table>
<thead>
<tr>
<th>Concept</th>
<th>Number of Responses = Level of Difficulty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meiosis and Genetics</td>
<td>3</td>
</tr>
<tr>
<td>Evolution</td>
<td>3</td>
</tr>
<tr>
<td>Photosynthesis</td>
<td>2</td>
</tr>
<tr>
<td>Respiration</td>
<td>1</td>
</tr>
<tr>
<td>Enzymes</td>
<td>1</td>
</tr>
<tr>
<td>Osmosis/concentrations</td>
<td>1</td>
</tr>
<tr>
<td>Protein synthesis</td>
<td>1</td>
</tr>
<tr>
<td>Probability</td>
<td>1</td>
</tr>
<tr>
<td>Homeostasis</td>
<td>2</td>
</tr>
<tr>
<td>Dynamics and Change</td>
<td>1</td>
</tr>
<tr>
<td>Surface Area to Volume</td>
<td>2</td>
</tr>
<tr>
<td>Scale</td>
<td>3</td>
</tr>
<tr>
<td>Energy</td>
<td>1</td>
</tr>
</tbody>
</table>
Ranking of concepts

Number of responses

- Not difficult
- Difficult
- Very Difficult

Concepts:
- Meiosis
- Mendelian Genetics
- Protein synthesis
- DNA
- Cell growth
- Concentration/Molarity
- Osmosis/Diffusion
- Evolution
- Population
- Nerve impulses
- Homeostasis
- Respiration
- Photosynthesis
- Biochemical reactions
- Enzymes
The relationship between troublesome, conceptually difficult concepts, basic and fundamental key concepts, discipline concepts and threshold concepts and threshold epistemes (Ross et al, 2009).
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
  1. 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 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


Percentage students identified concept

Intervention avg Control avg
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

<table>
<thead>
<tr>
<th>Keywords</th>
<th>Intervention</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration of molecules</td>
<td>4.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Movement of molecules</td>
<td>35.0</td>
<td>25.0</td>
</tr>
<tr>
<td>Size</td>
<td>15.0</td>
<td>20.0</td>
</tr>
<tr>
<td>Distance</td>
<td>1.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Transport</td>
<td>30.0</td>
<td>30.0</td>
</tr>
<tr>
<td>Scale</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Space</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Diffusion</td>
<td>5.0</td>
<td>5.0</td>
</tr>
</tbody>
</table>
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)