HOW TO DEVELOP AND USE CONCEPT INVENTORIES IN BIOLOGY

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OUTLINE

- Scientific Teaching
- What is a concept inventory?
- Development of concept inventories
- Examples
- Applications
- Wrap up

WHAT IS SCIENTIFIC TEACHING?

Handelsman *et al.* 2004. "Scientific Teaching". *Science* 304: 521-522.

(135+ citations as of June, 2011)

SCIENTIFIC TEACHING

- 1989 AAAS report "Science for all Americans" - reform in science education should be founded on scientific teaching
- 2011 – AAAS "Vision and change in undergraduate biology education: a call to action"
- Teaching is approached with the same rigour as science

WHAT ARE OUR PRIMARY GOALS AS TEACHERS?

A suitable educational goal is to have students thinking more like experts and approaching the mastery of the subject like an expert.

Thus, it is desirable to have test instruments that measure student thinking on a scale that distinguishes between novice and expert thinking. - Adams and Wieman

WHAT IS A CONCEPT INVENTORY?

A concept inventory is an outline of core knowledge and concepts for a given field and a collection of multiple choice questions designed to probe student understanding of these fundamental concepts.

- Redish, 2000

HOW DO CONCEPT INVENTORIES DIFFER FROM STUDENT ASSESSMENT?

- C.I.s probe students' conceptual understanding.
- C.I.s are based on research into student misconceptions.
- C.I. distracters are chosen to reflect common student misconceptions.

The primary goal [of a concept inventory] is not to obtain a summative assessment of student learning; rather, it is to provide formative assessment of teaching.

- Adams and Wieman

HOW TO DEVELOP A CONCEPT INVENTORY

Adams W, Wieman C. 2010. *Development and validation of instruments to measure learning of expert-like thinking.* International Journal of Science Education.

HOW TO DEVELOP A CONCEPT INVENTORY

STEP 1. Identification of key concepts by instructors

EXAMPLE: MEIOSIS CONCEPT INVENTORY

Two of the major meiosis concepts tested:

- How are microscopic events visualized?
- How do the chromosomal changes that occur during meiosis relate to the genetic consequences of this process?

HOW TO DEVELOP A CONCEPT INVENTORY

STEP 2. Qualitative research into student misconceptions

MISCONCEPTIONS - MEIOSIS

- How are microscopic events visualized?
  - Cells are flat
  - Stages are distinct
  - Chromosomes are always "X"-shaped
- How do the chromosomal changes that occur during meiosis relate to the genetic consequences of this process?
  - The typical "X" depiction of chromosomes is actually homologues pairing
  - Plants are haploid and reproduce asexually, animals are diploid and reproduce sexually
  - DNA replication occurs in prophase I, crossing over in metaphase I

EXAMPLE: SPECIATION CONCEPT INVENTORY

- A species consists of one or more populations of individuals.
- Speciation may be a slow, quick, or indefinite process.
- Speciation does not require natural selection and may be the result of purely random processes.

YOUR TURN!

- Turn to your neighbour and…
- Each choose a **topic** within your field/s
- Identify 1-2 concepts in each topic that students struggle with

MISCONCEPTIONS - SPECIATION

- New species only arise through the combination of existing types; associated with an essentialist (creationist?) conceptualization of species.
- Speciation requires natural selection, and that natural selection must be the result of environmental change.
- Reproductive isolation of populations is the only possible mechanism of speciation.

HOW TO DEVELOP A CONCEPT INVENTORY

STEP 3. Development of a Multiple Choice test in which student misconceptions are used as distractors

SPECIATION C.I. – BUILDING A QUESTION

Concept	Question	Distractors	Misconceptions
Speciation does not require natural selection (due to environmental change or otherwise), and may be the result of purely random processes.	Q11) Which of the following statements is/are correct? i. Speciation CANNOT happen without natural selection. ii. Speciation CANNOT happen without environmental change. iii. Speciation CAN be the result of random processes. a) iii only	b) i only	b) Speciation requires natural selection.
		c) both i and ii	c) Speciation requires natural selection, and that natural selection must be the result of environmental change.
		d) both i and iii	d) Speciation requires natural selection, but may also involve random processes.
		e) i, ii, and iii	e) Speciation requires natural selection (resulting from environmental change), but may also involve random processes.

SPECIATION CONCEPT INVENTORY - TOPICS

- Species Definition (1)
- Alternative Species Concepts (3)
- Intra- versus Interspecific Variation (2)

- Definition of Speciation (1)
- Speciation and Time Scale (1)
- Relationship between Mutation, Evolution, and Speciation (2)
- Relationship between Selection, Adaptation, and Speciation (2)

- Reproductive Isolation and Gene Flow (2)
- Speciation and Genetic Drift (1)
- Mechanisms of Divergence (4)
- Speciation and Hybridization (2)

HOW TO DEVELOP A CONCEPT INVENTORY

STEP 4. Validation of Questions
Meet with students - validation interviews answering test questions 'think-aloud'.

YOUR TURN!

Take turns interviewing each other with example speciation questions.

Concept 1: What is a species?

Concept 2: How does speciation happen?

- Is anything unclear?
- How would you change the question?
- Do you understand the thought process?

HOW TO DEVELOP A CONCEPT INVENTORY

STEP 5. Administer pre-tests (before instruction) and post-tests (after instruction) to a large class, typically several hundred.

STEP 6. Statistical analyses

WHAT CAN WE DO WITH C.I.S?

- Diagnose student misconceptions so that we can adjust instruction
- Assess teaching techniques

How else could you use concept inventories?

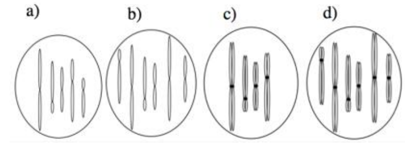
EXAMPLE: APPLICATION OF THE MEIOSIS CI

Biology 121: Ecology, Genetics & Evolution

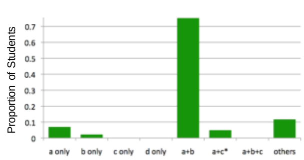
- Lecture only
- Program requirement/prerequisite for other faculties
- Over 2100 students per year – 10 lecture sections
- Changing instructor pool

DIAGNOSING MISCONCEPTIONS

One or more of the cells shown below are haploid. Which one(s) is it / are they?

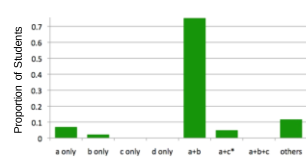


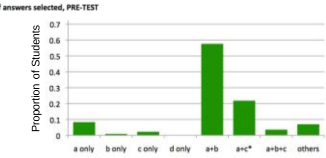
TARGETING TEACHING TO ADDRESS MISCONCEPTIONS



2010, n=148

TARGETING TEACHING TO ADDRESS MISCONCEPTIONS





2010, n=148

ASSESS TEACHING TECHNIQUES

Compare learning gain: the "gain" between pre- and post-test

- Calculation:
  score post-test – score pre-test
  max. score – score pre-test
- Example: pre-test 3/8; post-test 6/8
  Relative learning gain for that student:
  (6-3)/(8-3) = 3/5 or .6

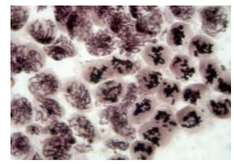
ASSESSING THE EFFECTS OF A MEIOSIS ACTIVITY

We tested 3 lecture sections:

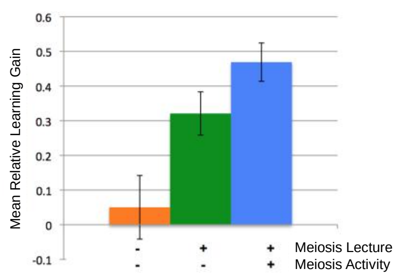
A: pre-test, post test (n=80)

B: pre-test, lecture, post test (n=148)

C: pre-test, lecture, activity, post test (n=133)



RESULTS: LEARNING GAIN



Error bars = 95% Confidence Intervals

SHARING C.I. INFORMATION

- Central repository (for instructors only)
- Posting of inventory questions, and student misconceptions
- Sharing activities that enhance student learning gain
- Sharing what we learn from our students

YOUR TURN!

- Select C.I. in your area
- Think about an activity you could do to enhance students' understanding of concept(s)
- How could you use the C.I. to assess the learning gain (i.e., how could you use the C.I. in scientific teaching)?

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