UNIVERSITY OF CALGARY

Less Traditional - More Conceptual: Enhancing Student Learning in First-Year Biology

Cindy Graham, Heather Addy, William Huddleston

1. Rationale for moving from traditional to conceptual organization in first-year biology

2. Creating a classroom environment that encourages learning

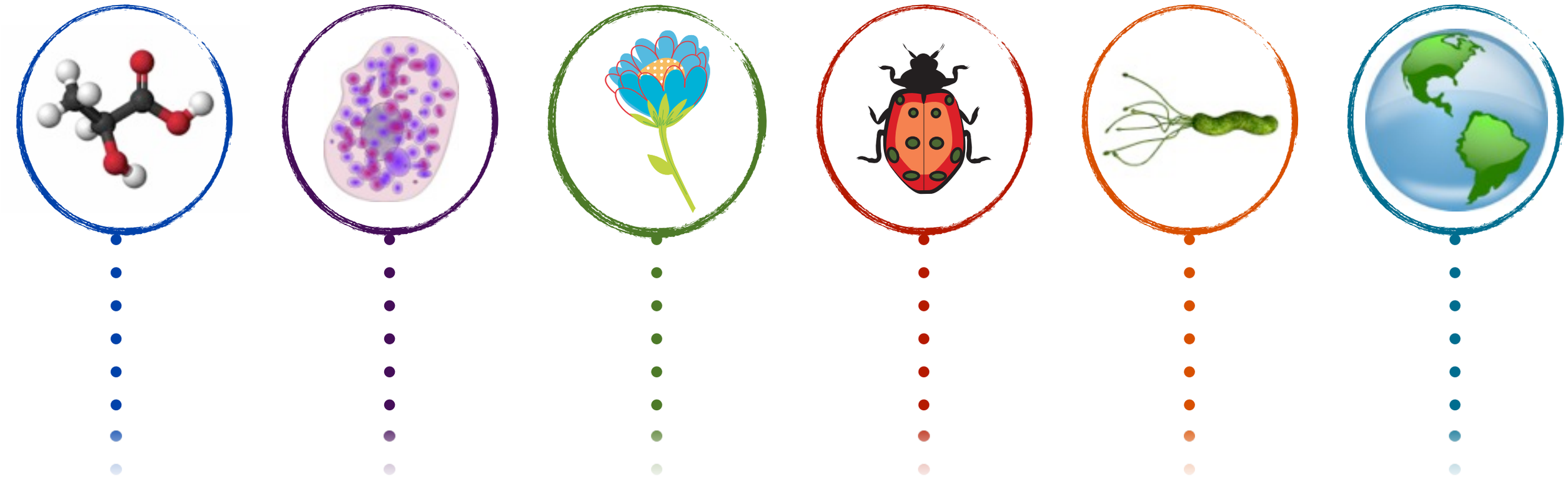
3. Research design and participants

4. Research Findings

5. Next Steps

Traditional Organization of the Biology Curriculum

Core courses introduce “disciplines”, not biology



Integrated Understanding of Core Concepts

Student and Faculty Perspectives of Core Courses

Students

Repetition from high school and between core courses

Focus on memorization of a LOT of detail

Links between courses weak

Few opportunities for feedback on lecture content

Lab experience could be improved

Faculty

Some content repeated in several different courses

Content delivered not clearly "core" knowledge

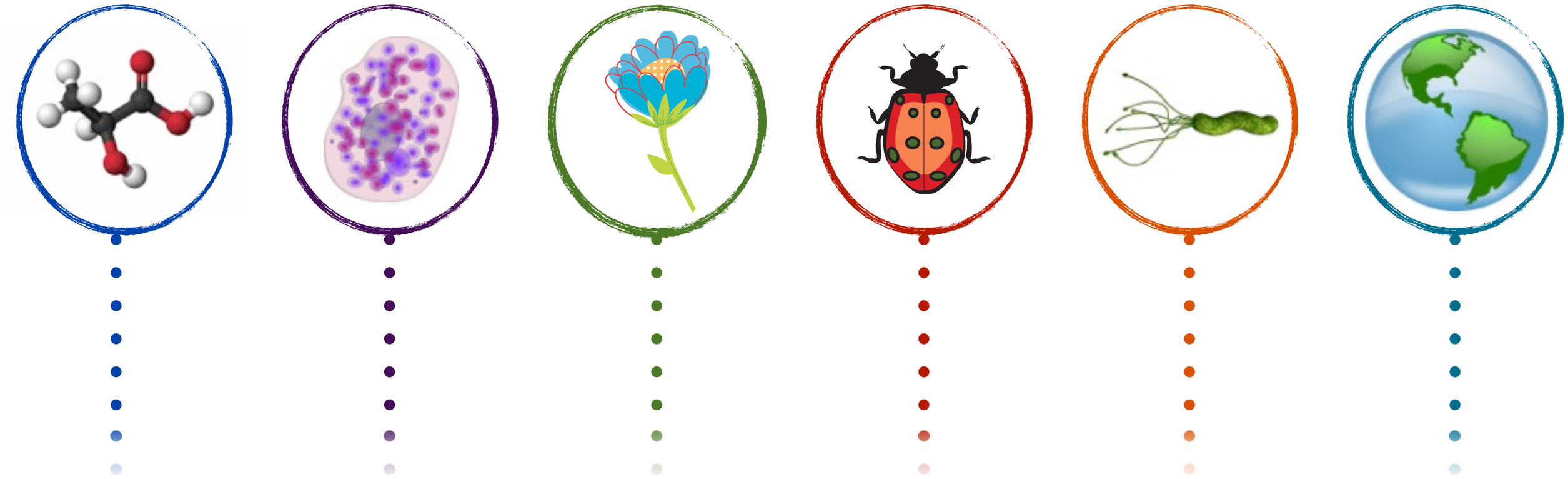
Knowledge transfer between courses weak

Inconsistent learning experience between courses

Lab experience not "authentic" in all courses

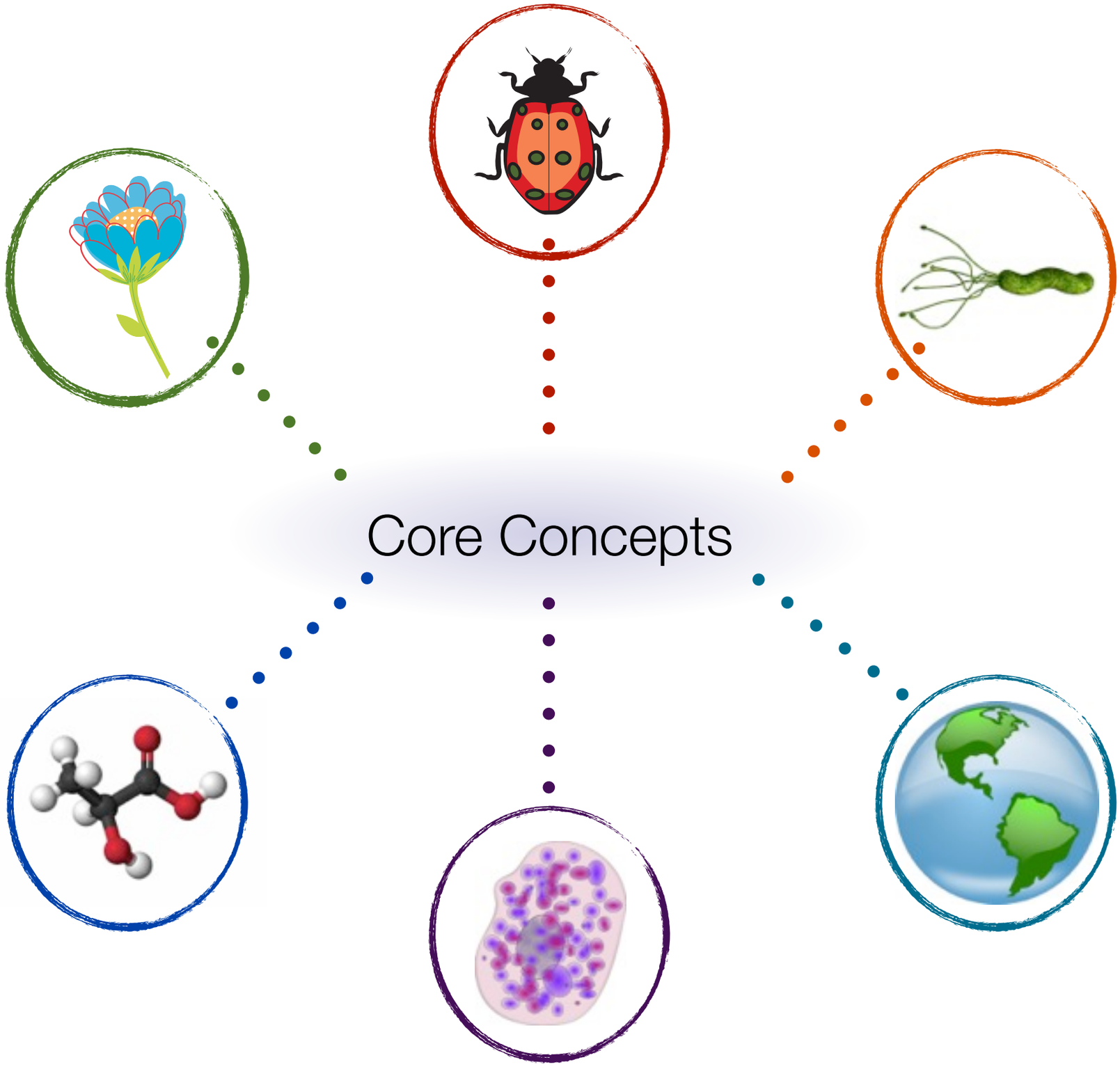
Traditional Organization of the Biology Curriculum

Core courses introduce “disciplines”, not biology



Integrated Understanding of Core Concepts

Conceptual Organization of the Biology Curriculum



Vision and Change – 2011

Core Concepts for Biological Literacy

Evolution

Structure and Function

Information Flow, Exchange and Storage

Pathways and Transformation of Energy and Matter

Systems

Core Competencies & Disciplinary Practice

Applying the Process of Science

Quantitative Reasoning

Modeling and Simulation

Tapping into Interdisciplinarity

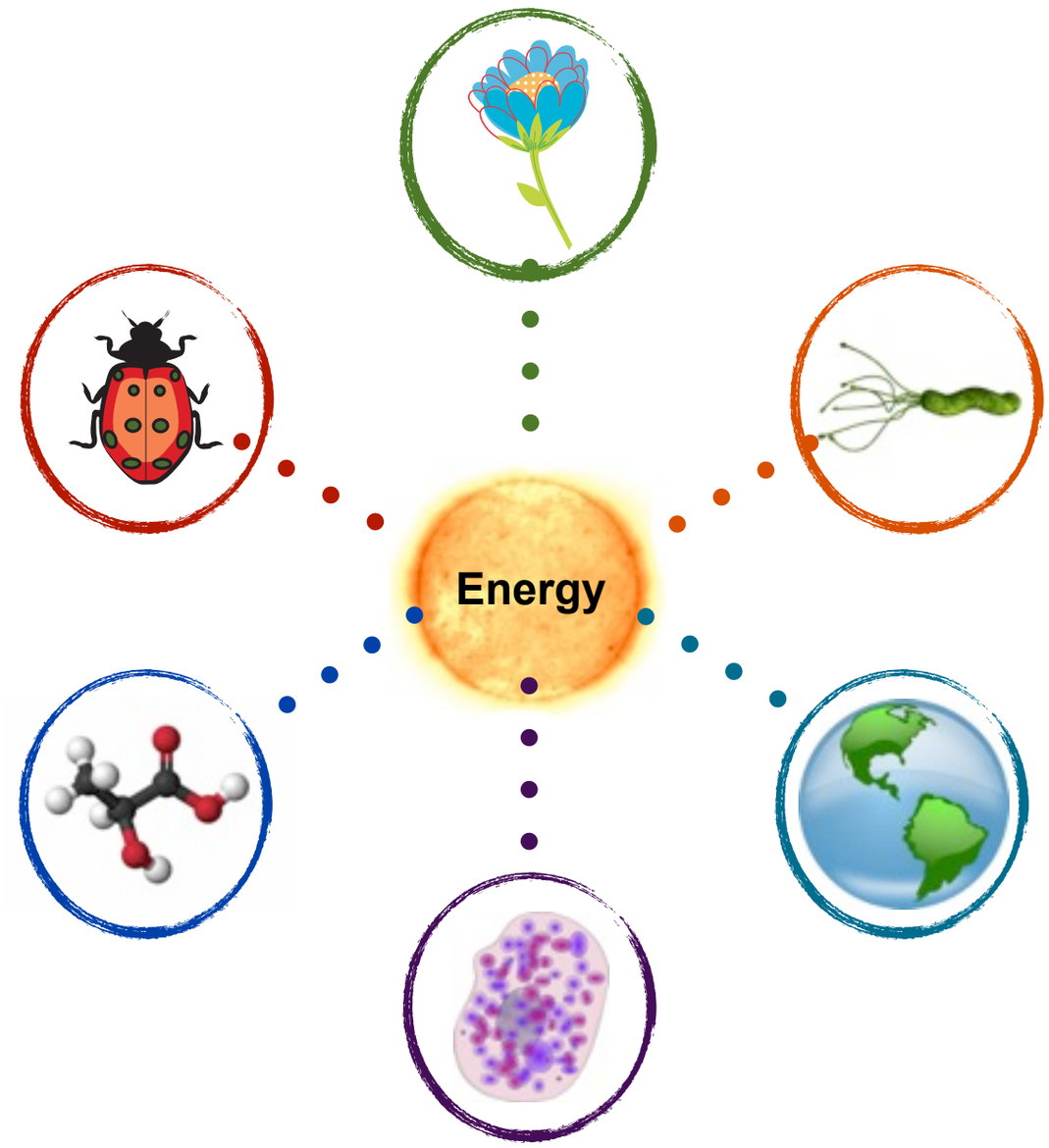
Communication and Collaboration

Relating Science and Society

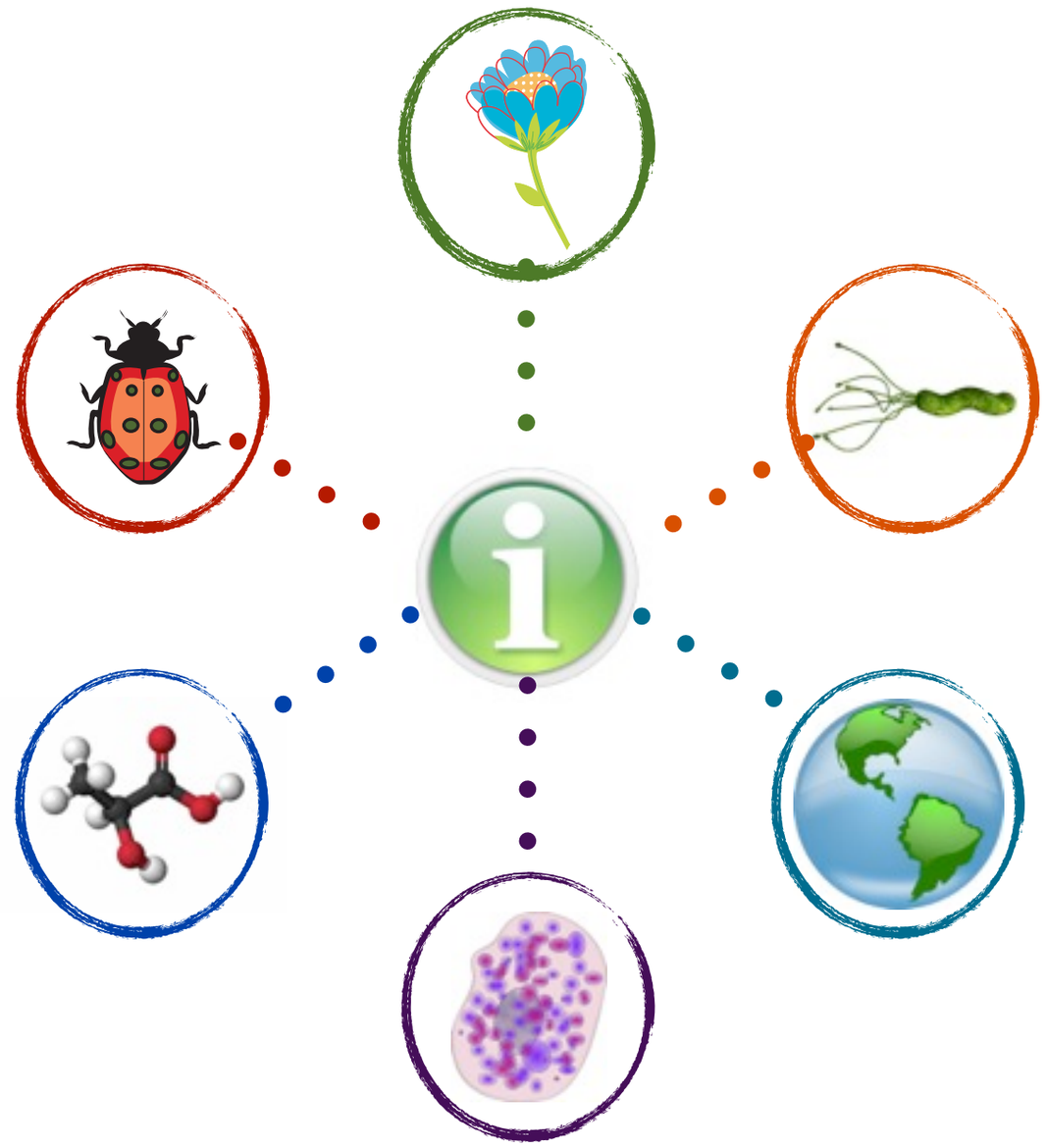
Vision and Change in Undergraduate Biology Education: A Call to Action. http://visionandchange.org

Organizing the First-Year Biology Curriculum

Energy Flow in Biological Systems



DNA, Inheritance and Evolution



Using Class Time for Learning not just Listening

Learn before Lecture Activities

Weekly quiz or online tutorial guided by desired learning outcomes.

Learn more about how "Learn before lecture" strategies improve learning outcomes in: Moravec et al. 2010. CBE Life Sci Educ 9(4):473-81.

Using Class Time for Learning not just Listening

Case Studies

Membranes and Ecstasy

Rotenone/Arsenic Poisoning and Respiration

Energetics of Vampire Bats

Jellyfish Blooms - Ecosystem Energetics

Using Class Time for Learning not just Listening

Concept-Based Questioning

In-class assignments

Clickers

Why does the rate of glucose consumption change after cells are placed in the anaerobic environment?

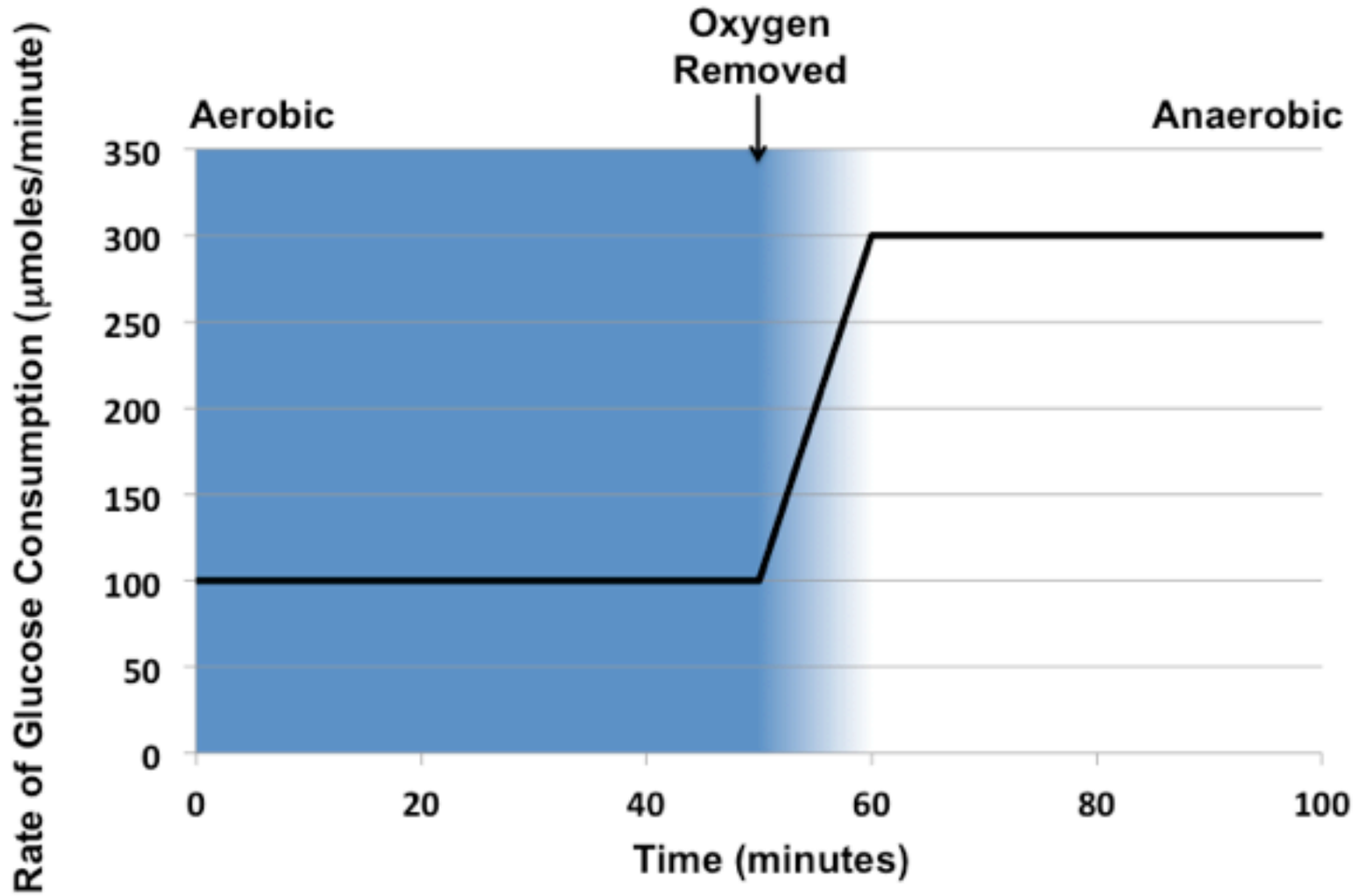


Figure 1: Change in Rate of Glucose Consumption by a Facultative Anaerobe Transferred from an Aerobic Environment to an Anaerobic Environment

Using Class Time for Learning not just Listening

Learn before Lecture

Case Studies

Concept-Based Questioning

- In-class assignments
- Clickers
- Written exam questions

Scaffolds for Developing Complex Skills

Focusing goals in

- Reading and using primary literature
- Writing lab report elements
- Focus on experimental design

Investigating the Impact of Course Redesign

What motivates our students?

How do students approach learning new information?

What do our students already know about energy?

What do our students already know about how science is done?

Learning Orientations component of Experiences of Teaching & Learning Questionnaire (ETLQ)

ASSIST – Approaches to Study Skills Inventory for Students

Concept Pre-Test
Multiple Choice and Written Questions

Science Process Skills Pre-Test

What experiences/challenges did they have?

How much did they learn?

ETLQ - Experiences of Teaching & Learning Questionnaire

Concept Post-Test

Science Process Skills Post-Test

Energy pre/post-test multiple choice questions from Biological Concept Inventory, Photosynthesis and Respiration Diagnostic Question Clusters.
Written question similar to Bissell AN, Lemons PP. 2006. Bioscience 56(1):66-72
Information on ASSIST and ETLQ surveys can be found at http://www.etl.tla.ed.ac.uk

Research Design and Participants

Traditional Course: Biology 231

Evaluated in Fall 2010

2 Lecture Sections

67.6% participation (716 consented/1059 total)

Mean age 18.6; Female 64.3%/Male 35.7%

Concept-Based Course: Biology 241

Evaluated in both Fall 2011 and Fall 2012

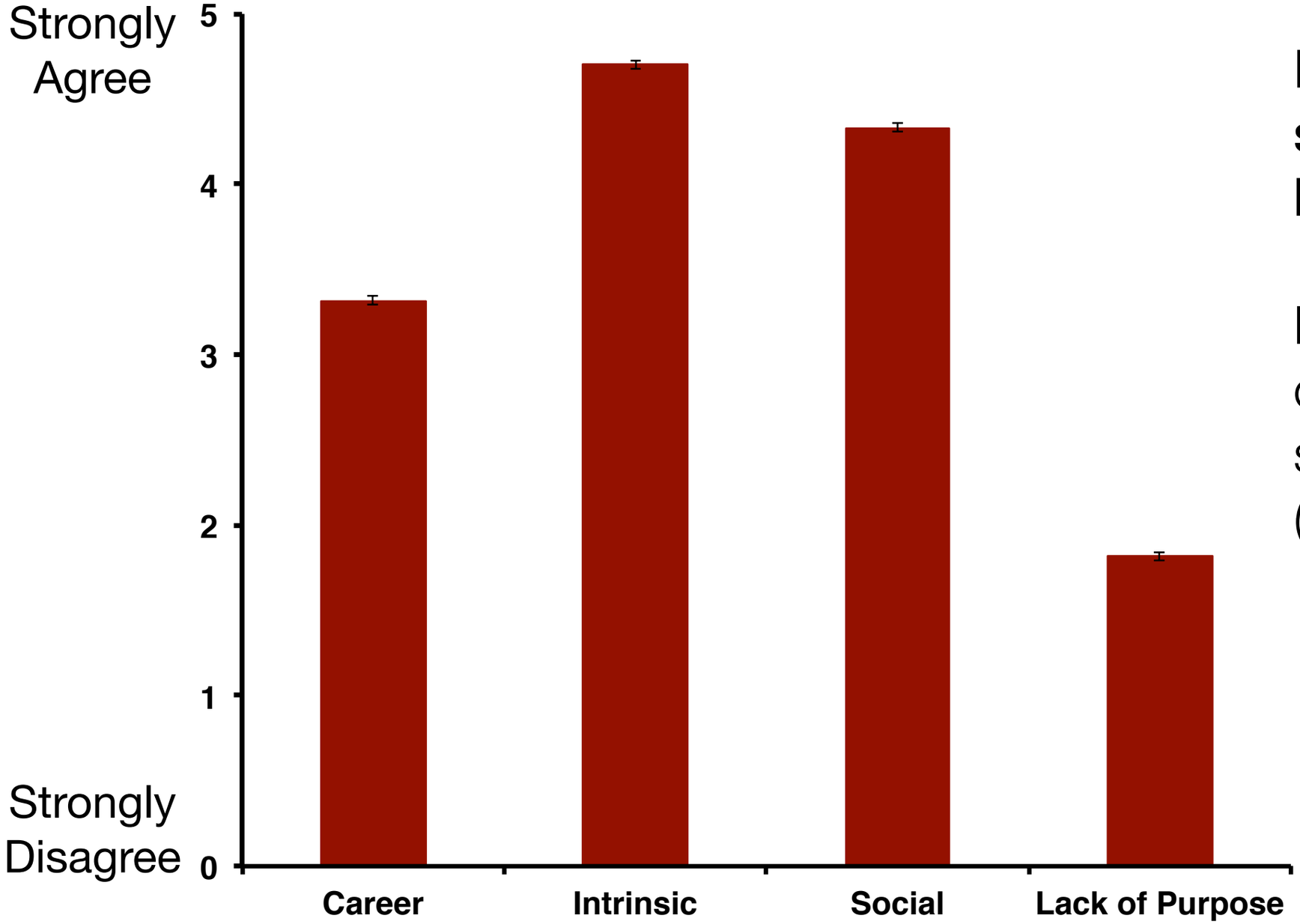
3 Lecture Sections

F11: 82.7% participation (927 consented/1121 total)

F12: 87.0% participation (963 consented/1107 total)

Mean age 18.9; Female 63.3%/Male 36.9%

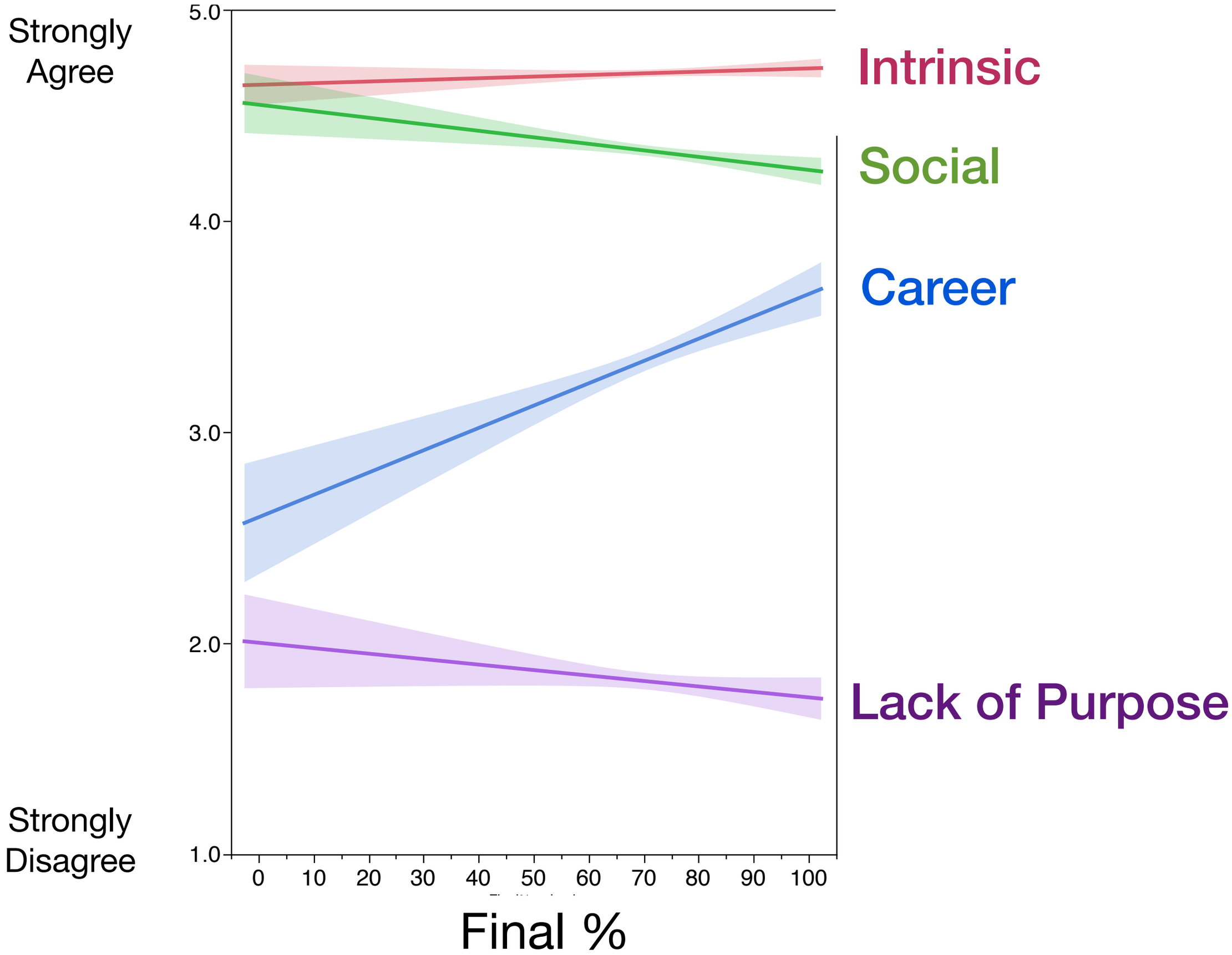
What motivates our students?



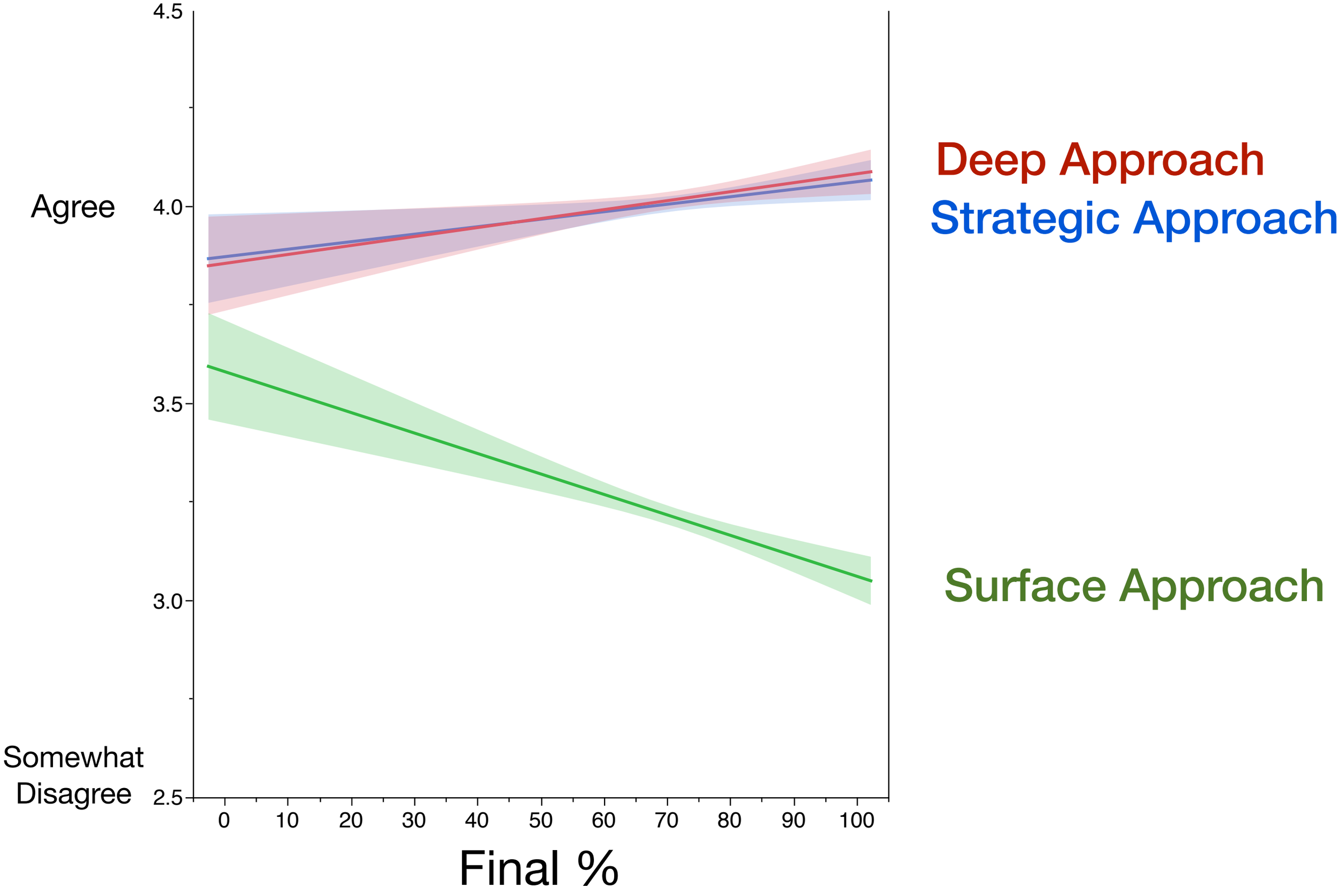
Responses from 2602 students in first-year biology.

No differences between courses, terms or lecture section were found (All p values <0.0001).

What motivates our students?

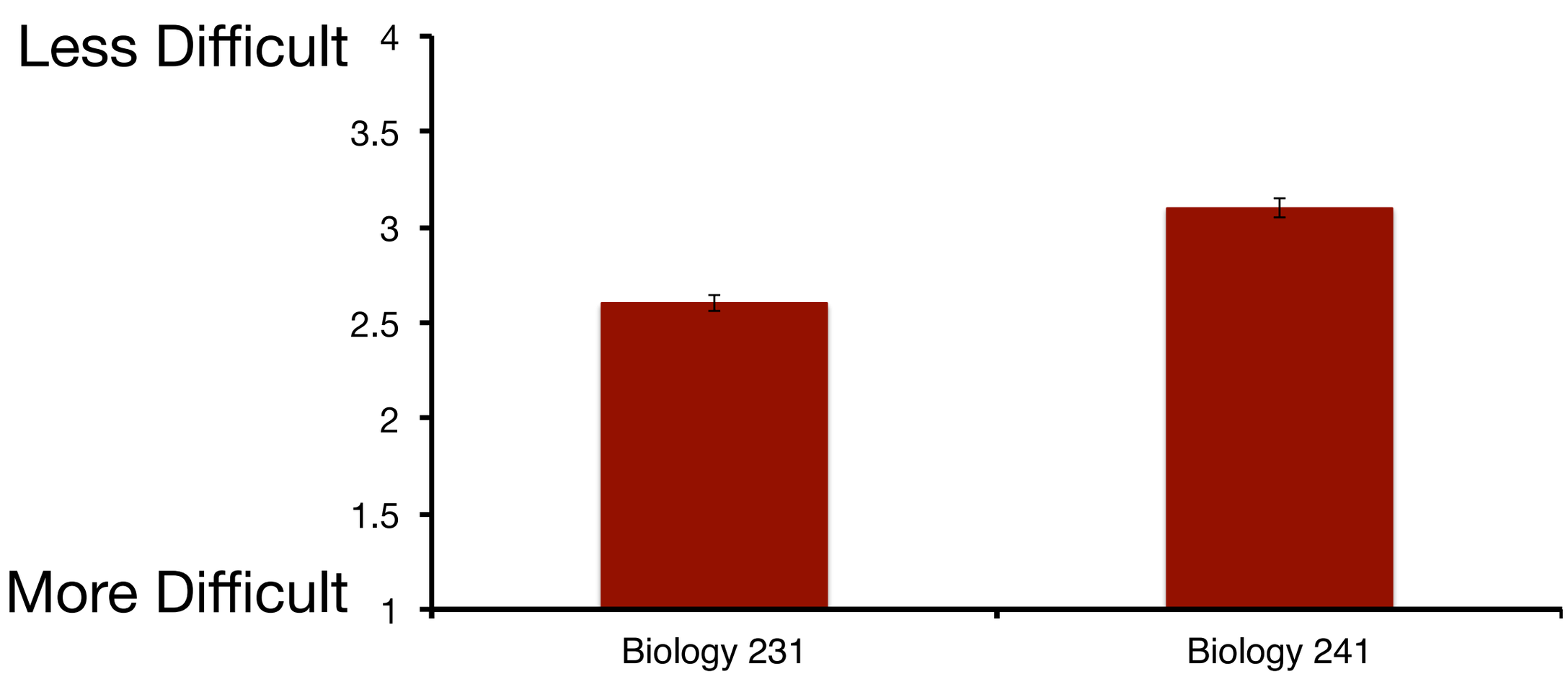


How do our students approach learning new information?

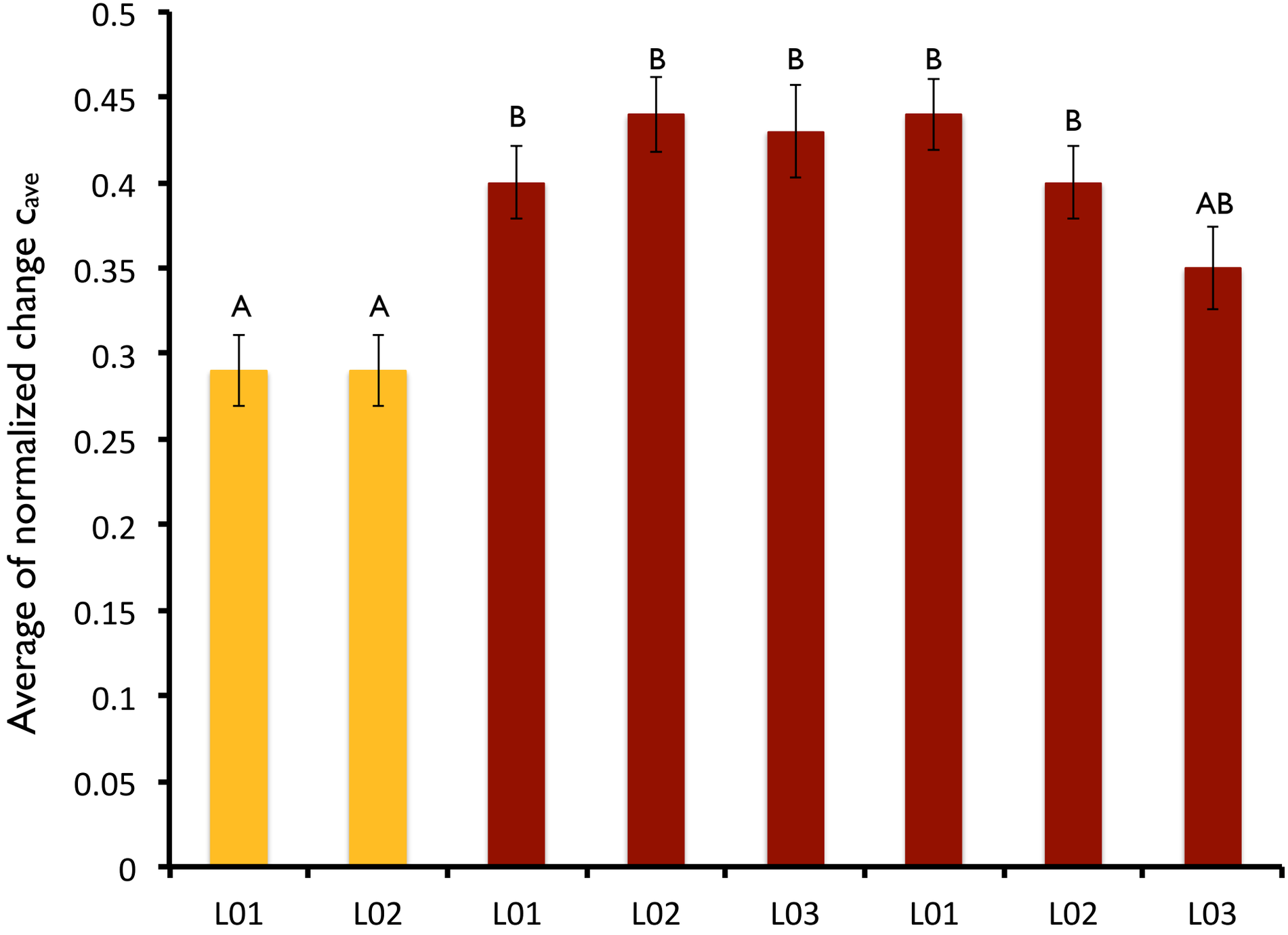


What experiences/challenges did they have?

- ☑ The ideas and problems I had to learn.
- ☑ The skills or technical procedures needed in this subject.
- ☑ Organizing and being responsible for my own learning



How much did they learn?

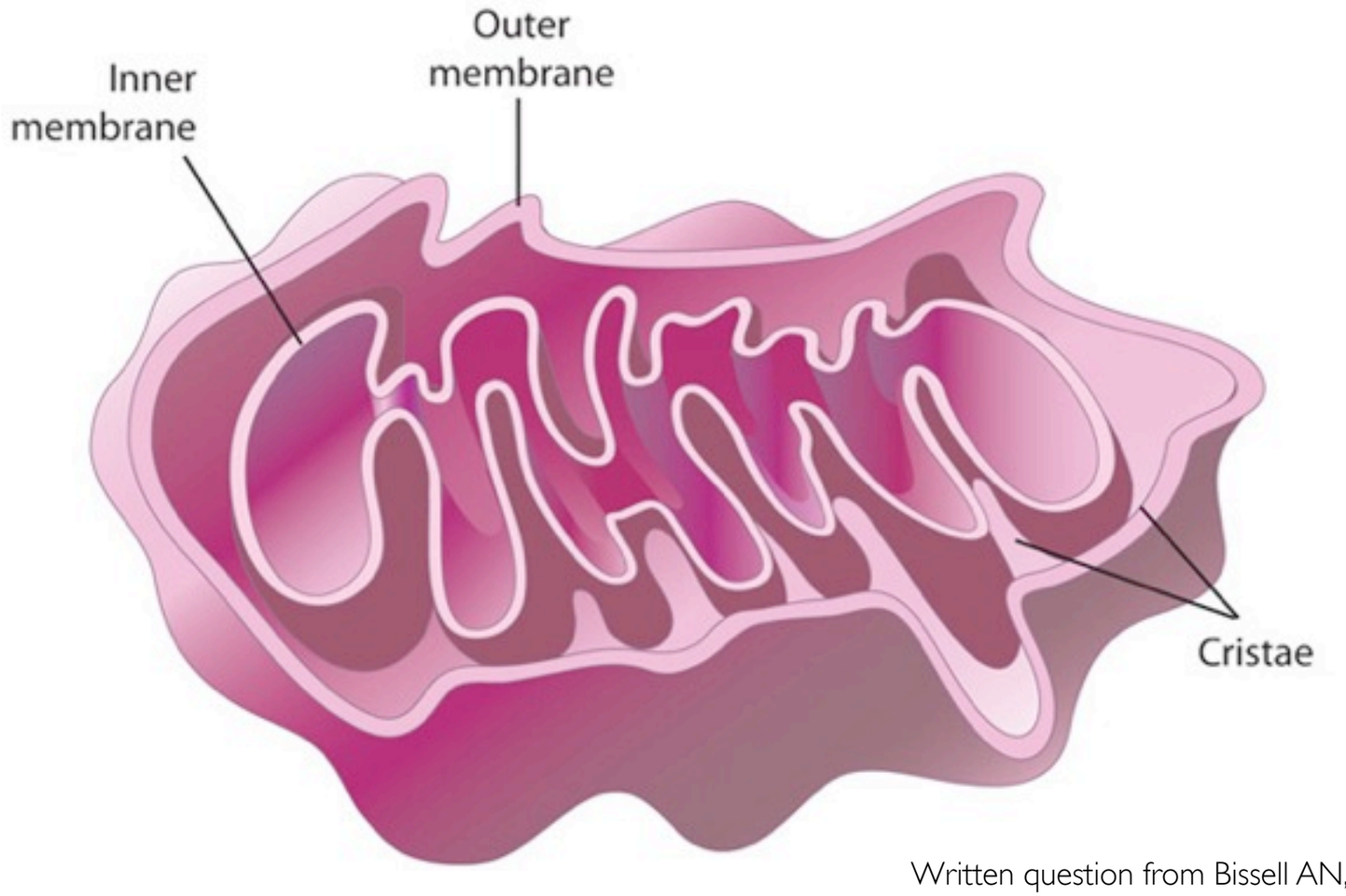


* Students come into first year biology with weak conceptual understandings of energy, evolution and information
* Students learn substantially more in concept-based courses

Marx JD, Cummings K. 2007. Normalized Change. American Journal of Physics 75(1):87-91.

Analysis of Written Concept Questions

In the 1940s, some physicians prescribed low doses of a drug called dinitrophenol (DNP) to help patients lose weight. The use of DNP as a "diet" pill was abandoned after a number of patients died. DNP works by uncoupling the machinery of the mitochondria by making the lipid bilayer of the inner mitochondrial membrane leaky to H^+. If someone took too high a dose of DNP or used DNP for a prolonged period of time, why might this drug be lethal?



Written question from Bissell AN, Lemons PP. 2006. Bioscience 56(1):66-72

Analysis of Written Concept Questions

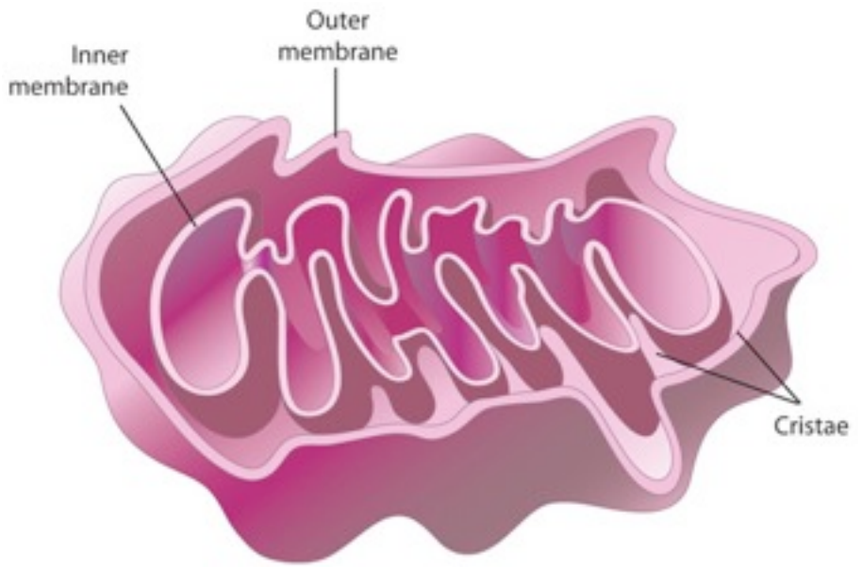
Having the higher concentration of the H^+ would make the cell become more acidic creating the spread and damage...

Student BIOL231-001

"This would increase the pH of the mitochondria and cause blood pH to be less than normal"

Student BIOL241-001

Issues of pH? Scale? Compartmentation?



It would cause an overflow of H^+ in the mitochondria causing it to explode...

Student BIOL241-001

"If the mitochondrial membrane became leaky to H^+, the mitochondria would actually have more H^+ inside than outside. This would result in osmisos [sic], where the H^+ would be transported outside the cell. It would also mean that fluid would be transported out, causing the cell to have less fluid then outside. The cell would shilver [sic] (get smaller) and eventually die."

Student BIOL231-002

Osmosis? Scale? Compartmentation?

Written question from Bissell AN, Lemons PP. 2006. Bioscience 56(1):66-72

Next Steps...

- ❑ Complete analysis of written concept questions.

- ❑ Development of new multiple choice questions to incorporate newly found misconceptions.

- ❑ Development of visualization activities to help students understand compartmentation and scale in terms of cell biology

- ❑ Complete analysis for DNA, Inheritance and Evolution course

Acknowledgements

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