Changing how we teach genetics through learning goals, assessments, and interactive learning

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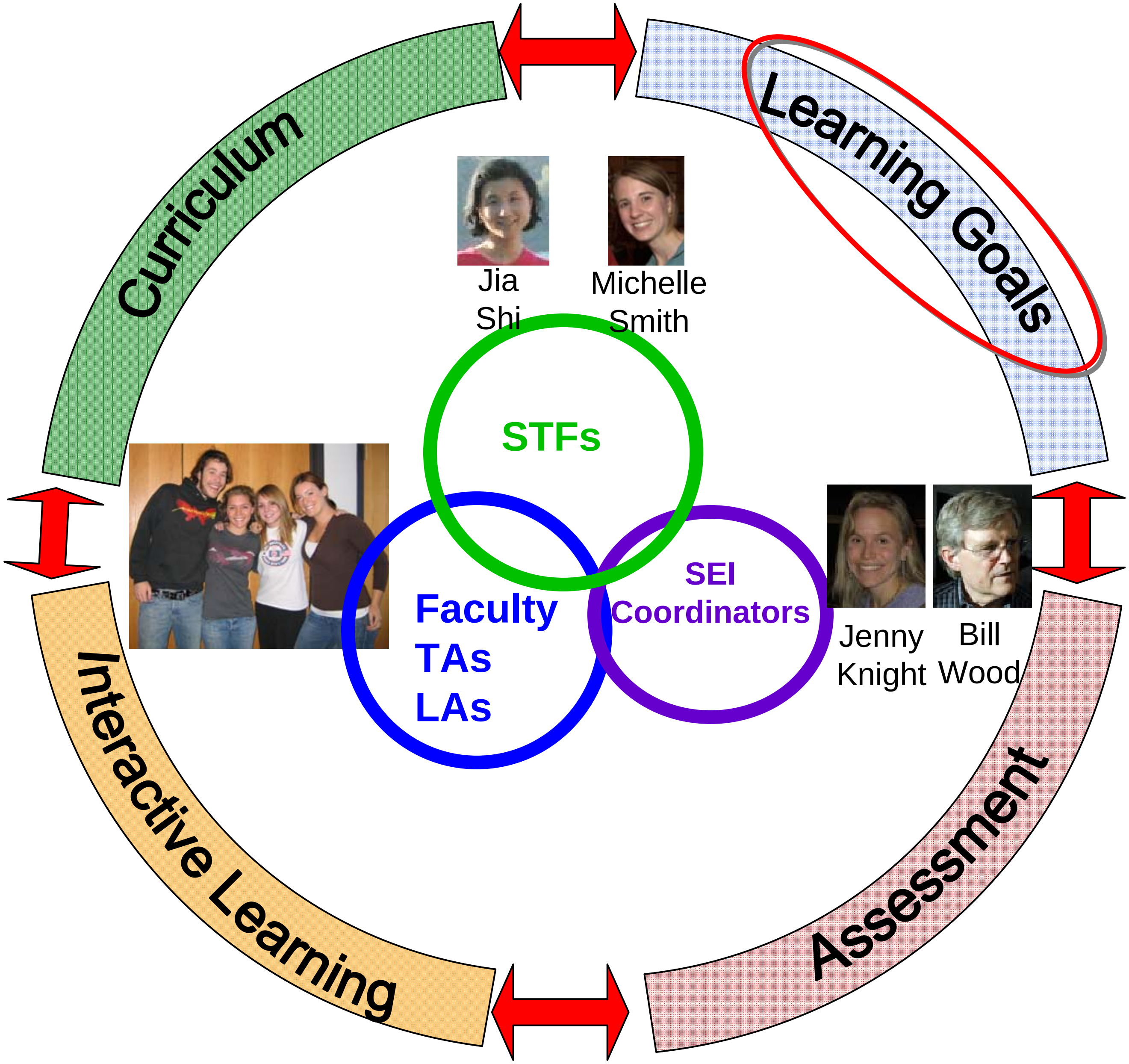
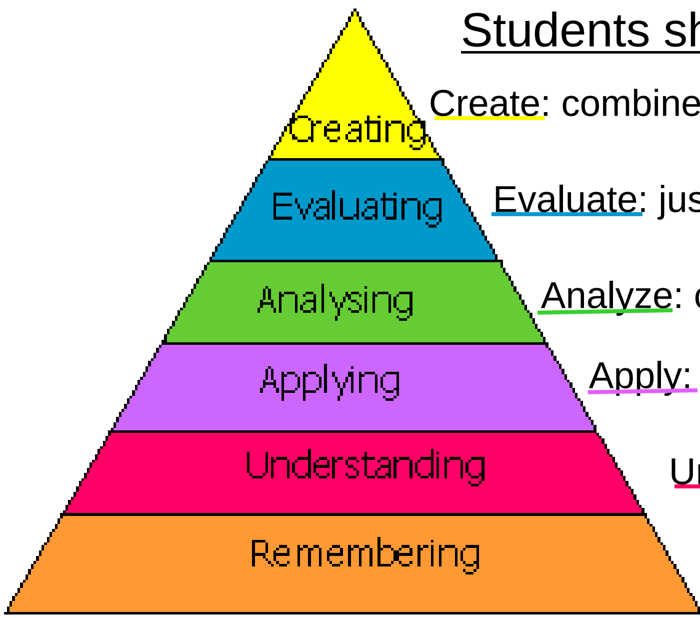
Organization of the MCDB Science Education Initiative



What are learning goals?

Statements that focus on the outcomes we expect of students when they complete the course

Based on Bloom’s Taxonomy



<u>Students should be able to:</u>

<u>Create</u>: combine ideas to create something new.

<u>Evaluate</u>: justify or defend a conceptual point of view.

<u>Analyze</u>: compare and distinguish between related concepts.

<u>Apply:</u> use learned information in a new situation.

<u>Understand:</u> explain ideas or concepts.

<u>Remember</u>: recall and restate learned information.

Modified version of Bloom’s taxonomy: http://www.odu.edu/educ/llschult/blooms_taxonomy.htm

Example of a genetics learning goal

Syllabus topic: Pedigree Analysis

Example of a course learning goal (10 total)

After completing this course, students should be able to:

Analyze phenotypic data and deduce possible modes of inheritance (e.g. dominant, recessive, autosomal, X-linked, cytoplasmic) from family histories.

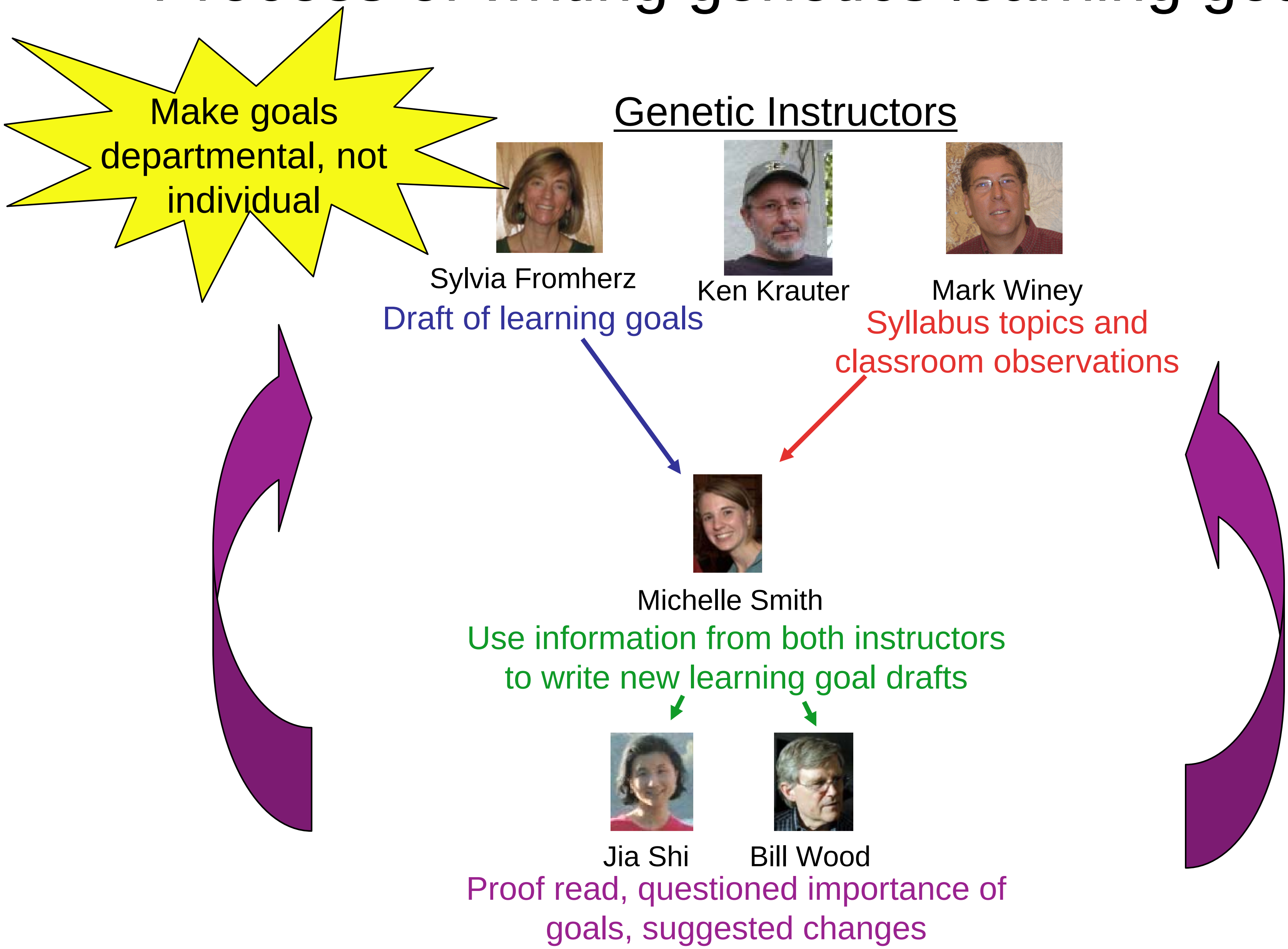
Sample of topic learning goals

Draw a pedigree based on information in a story problem.

Calculate the probability that an individual in a pedigree has a particular genotype.

Define the terms “incomplete penetrance,” “variable expressivity,” and “sex-limited phenotype,” and explain how these phenomena can complicate pedigree analysis.

Process of writing genetics learning goals

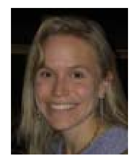


Genetics pre/post assessment

Michelle Smith

Bill Wood

MCDB faculty



Jenny Knight

MCDB faculty

Curriculum

Learning Goals

Assessment

Interactive Learning

The pre/post assessment is different from other genetics tests

Assessment is 25 multiple-choice questions that address the 10 course learning goals.

Jargon is used minimally in this assessment.

Assessment is given pre and post to measure learning gains.

The incorrect answers are designed to be attractive to students who do not fully understand genetics concepts.

Observations during homework study sessions

Student Interviews

Questions validated by interviews with students and faculty members.

Students at a variety of achievement levels helped with the development of the assessment

A students: verify that students get the right answer for the right reasons

B and C students: retain some misunderstandings that are useful as distracters

D students: look for non-content clues to the right answer

A single DNA nucleotide change of an A to a T occurs and is copied during replication; is this change in DNA sequence necessarily a mutation?

a) Yes, it is a change in the DNA sequence.
b) Yes, but only if the nucleotide change occurs in a sex cell (sperm or egg).
c) Yes, but only if the nucleotide change occurs in the coding part of a gene.
d) Yes, but only if the nucleotide change occurs in the coding part of a gene and alters the amino acid sequence of a protein.
e) No, because A and T are similar enough, they can substitute for each other.

Answer: a

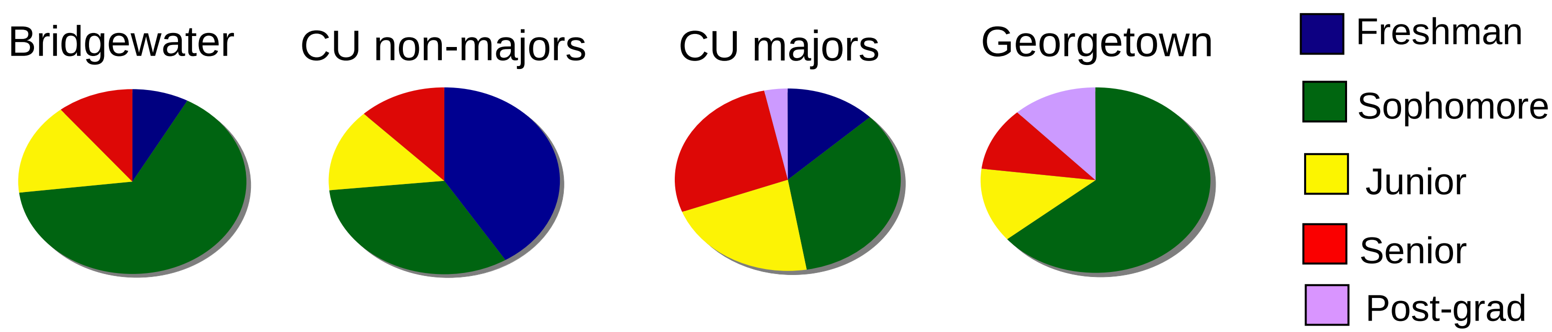
Student who earned a D in genetics: “I don’t like to see the word only in answers. Answers with only are never true. There are 4 yes answers and 1 no, so I will go with answer a).”

Genetics assessment was given at three quite different institutions this fall

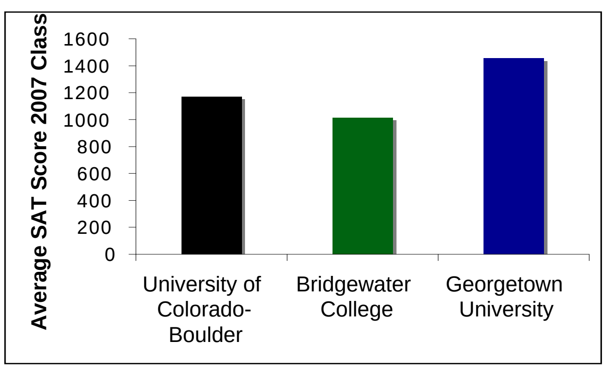
348 genetics students from CU-Boulder (majors and non-majors), Bridgewater College in Virginia, and Georgetown University in Washington, D.C.

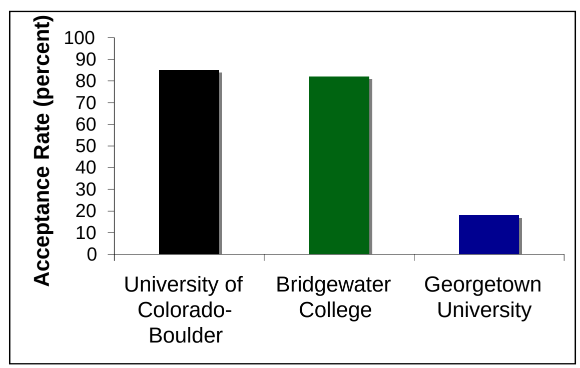
Prerequisites for students taking genetics are different

<u>Grade level of students:</u>

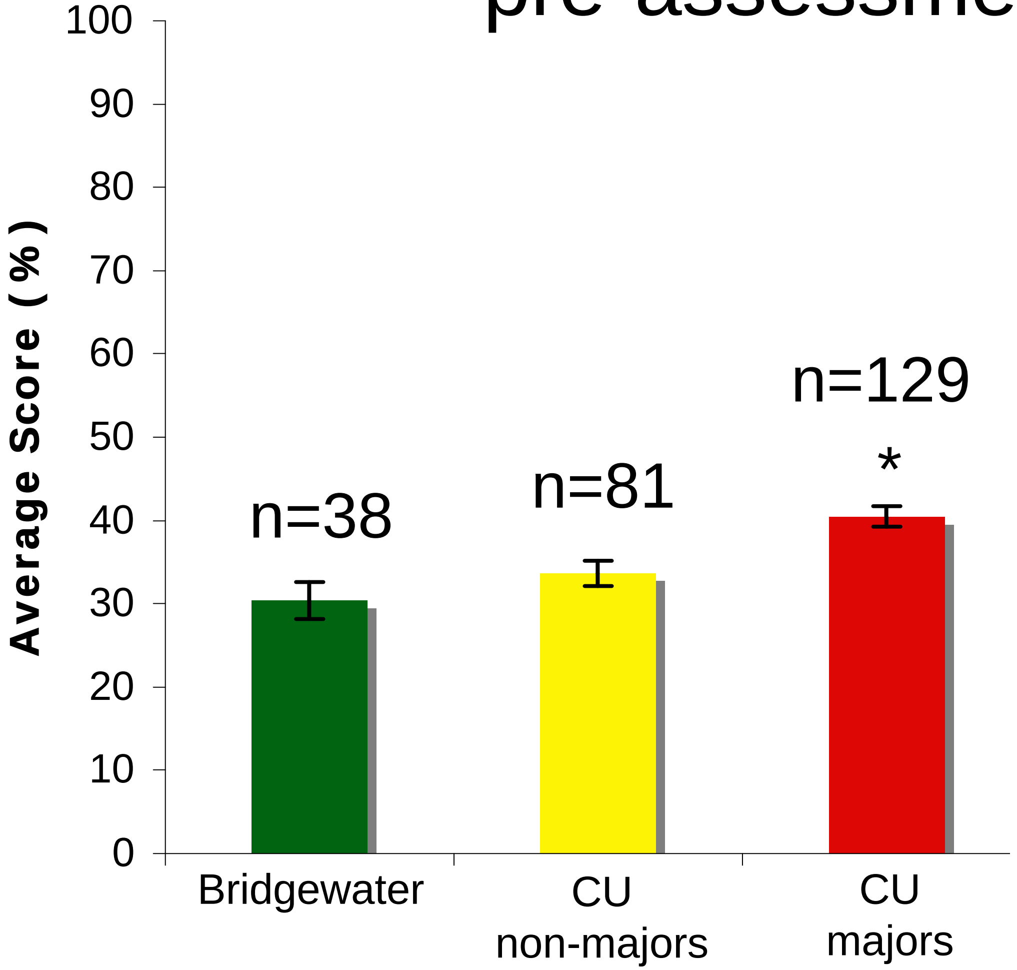


<u>Institution entrance statistics:</u>





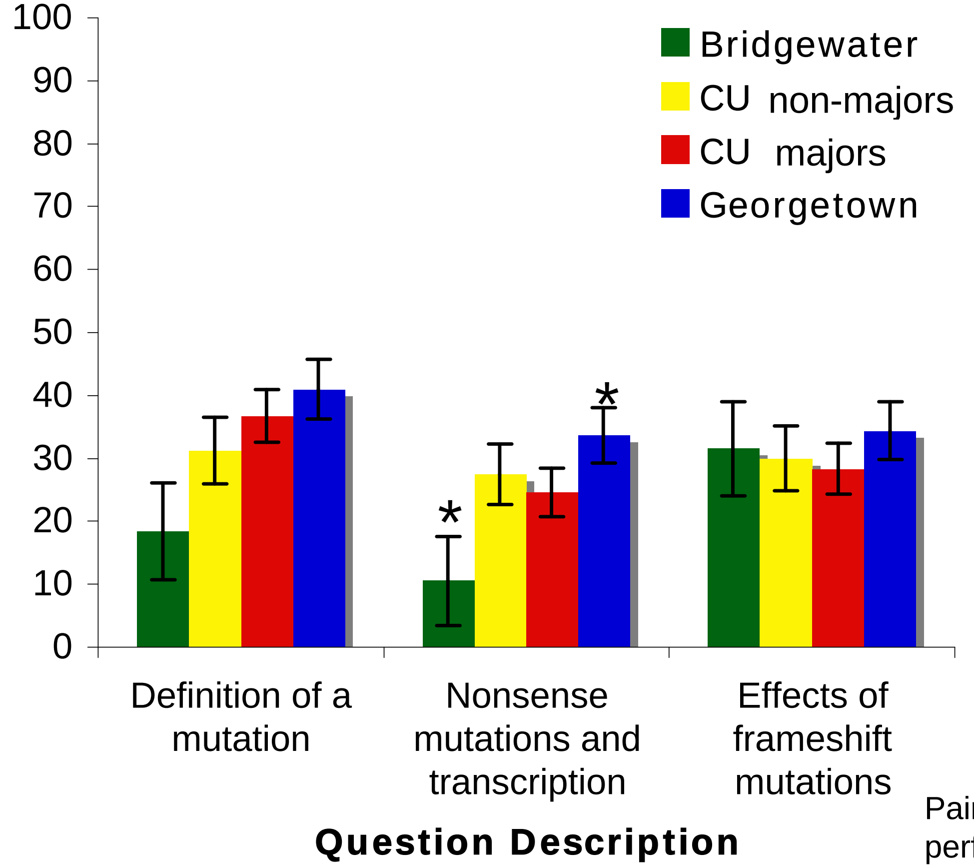
Overall performance on the genetics pre-assessment



Pairwise comparisons between means were performed with a Tukey post-hoc test (significance level set at $p<0.05$).

Example of wide-spread student conceptual problems

Learning goal: Compare different types of mutations and describe how each can affect genes, mRNA, and proteins.



Pairwise comparisons between means were performed with a Tukey post-hoc test (significance level set at $p<0.05$).

Most common conceptual problems on these topics

Many students think that:

1). A DNA nucleotide change is defined as a mutation only if the nucleotide change occurs in the coding part of a gene and/or alters the amino acid sequence of a protein.

2). A stop codon stops transcription.

3). The insertion of a nucleotide into the coding portion of a gene cannot result in a shorter protein.

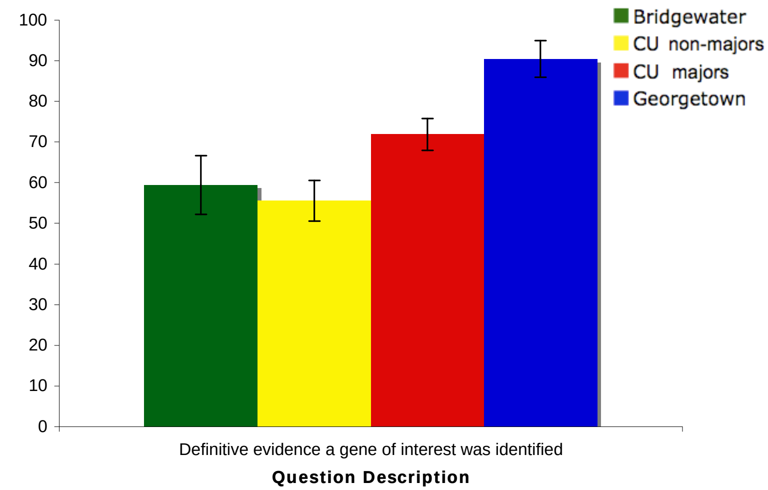
Conclusions from the genetics assessment development process

✓ We have developed a genetics assessment where the wrong answers are attractive to students who do not fully understand genetics concepts.

✓ We have revealed several common student misunderstandings at all three institutions.

Next we will…

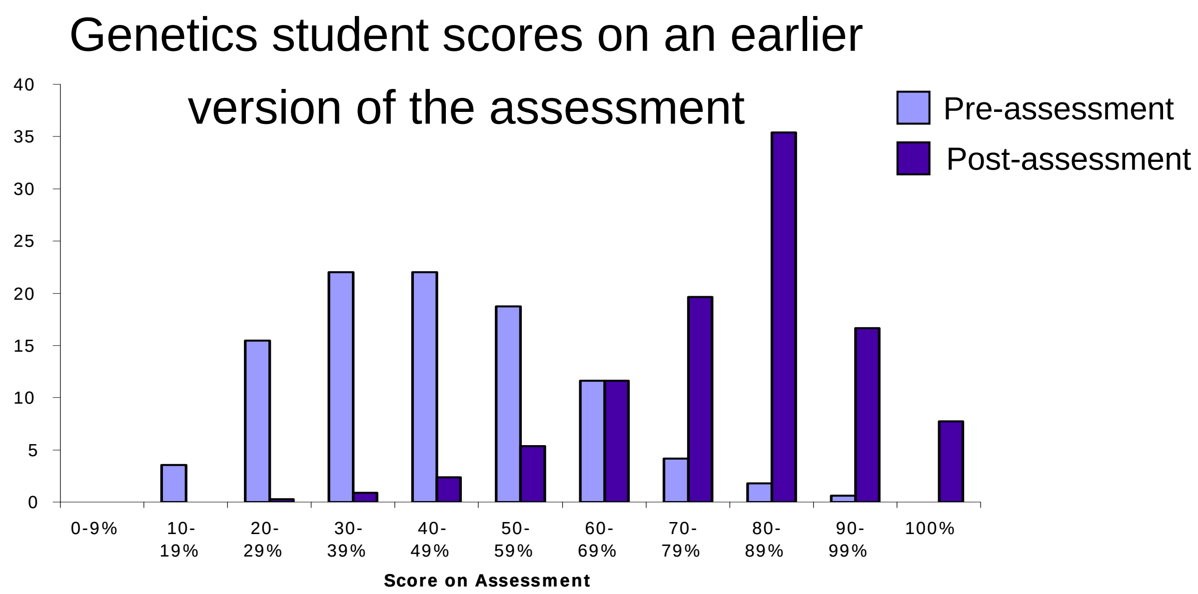
Address problems in the assessment.



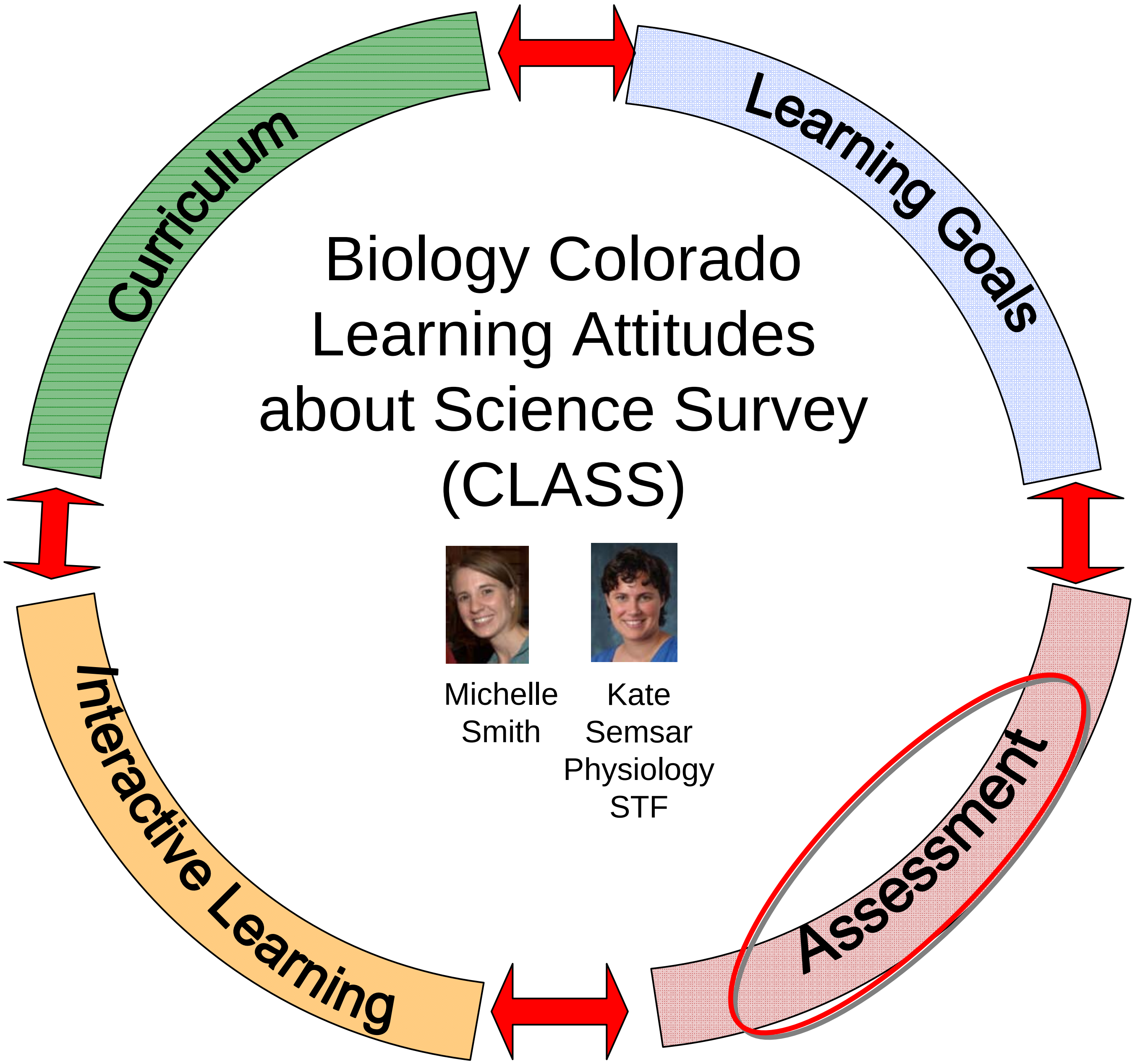
Continue to work with genetics instructors at multiple institutions to verify that our assessment tool is a widely useful and reliable instrument.

Genetics assessment will be used to gauge student learning and monitor curriculum change

Compare scores on the pre and post assessment to measure learning gains



Design tools to improve student conceptual learning


Curriculum
Learning Goals
Assessment
Interactive Learning
Biology Colorado Learning Attitudes about Science Survey (CLASS)
Michelle Smith
Kate Semsar Physiology STF

Differences between novice and expert learners concerning their beliefs about science

Novice		Expert
Isolated pieces of information	**content and structure**	Coherent framework of concepts
Handed down by authority No connection to the real world	**source**	Describes nature Established by experiments
Pattern matching to memorized recipes	**problem solving**	Use concept-based strategies. Widely applicable.

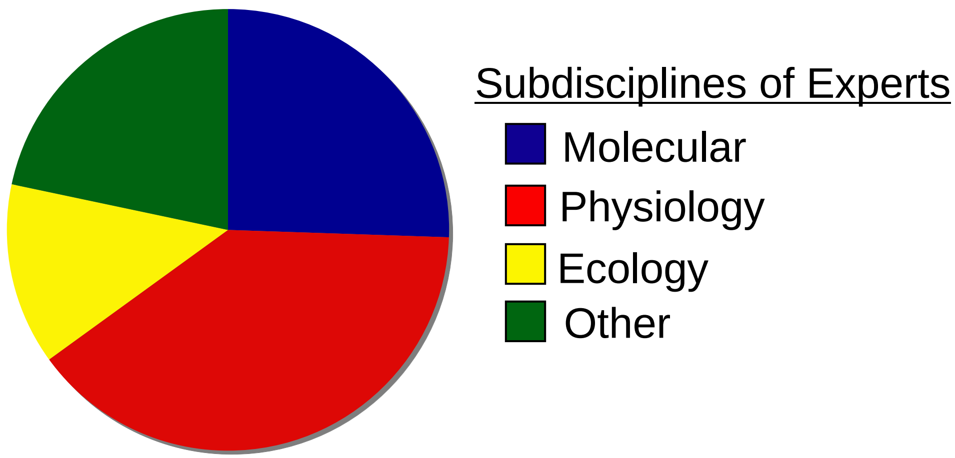
(adapted from David Hammer,*2000*).

Biology novices and experts

Over 2,000 students took the survey this fall

- General biology (Ecology and Evolutionary Biology)
- Introduction to molecular and cellular biology (MCDB)
- Genetics majors and non-majors (MCDB)
- Anatomy (Physiology)

80 Ph.D. experts have taken the same survey



Biology CLASS statements designed to distinguish novice and expert beliefs

Survey (8-10 minutes)

Likert scale

1. When I am solving a biology problem, I try to decide if my answer makes sense.
   Strongly Disagree 1 2 3 4 5 Strongly Agree
   not answered

2. I think about the biology I experience in everyday life.
   Strongly Disagree 1 2 3 4 5 Strongly Agree
   not answered

3. After I study a topic in biology and feel that I understand it, I have difficulty applying that information to answer questions on the same topic.
   Strongly Disagree 1 2 3 4 5 Strongly Agree
   not answered

4. Knowledge in biology consists of many disconnected topics.
   Strongly Disagree 1 2 3 4 5 Strongly Agree
   not answered

- Statements are based on the physics CLASS (Adams *et al.,* 2004)
- Student interviews on statements were conducted for clarity of interpretation (n=15)
- Experts have 80% or greater agreement on 34 of 44 statements
- Student responses are compared with experts

Students tend to shift from expert to novice beliefs in science courses!!

Statements are classified into categories (e.g.: personal interest, real world connections, problem solving)

Work in physics, chemistry, and geology has shown shifts towards novice thinking in introductory science courses (Adams *et al.,* 2006, Perkins *et al.,* 2007, Unpublished data from: Langdon, Stempien and Bair)

Preliminary evidence shows shifts towards novice thinking in General Biology (Ecology and Evolutionary Biology)

Largest shifts towards novice thinking:

It is important for the government to approve new scientific ideas before they can be widely accepted.

Mathematical skills are important for understanding biology.

I do not spend more than a few minutes stuck on a biology question before giving up or seeking help from someone else.

Largest shift towards expert thinking:

I think about the biology I experience in everyday life.

Future questions to be addressed by the Biology CLASS

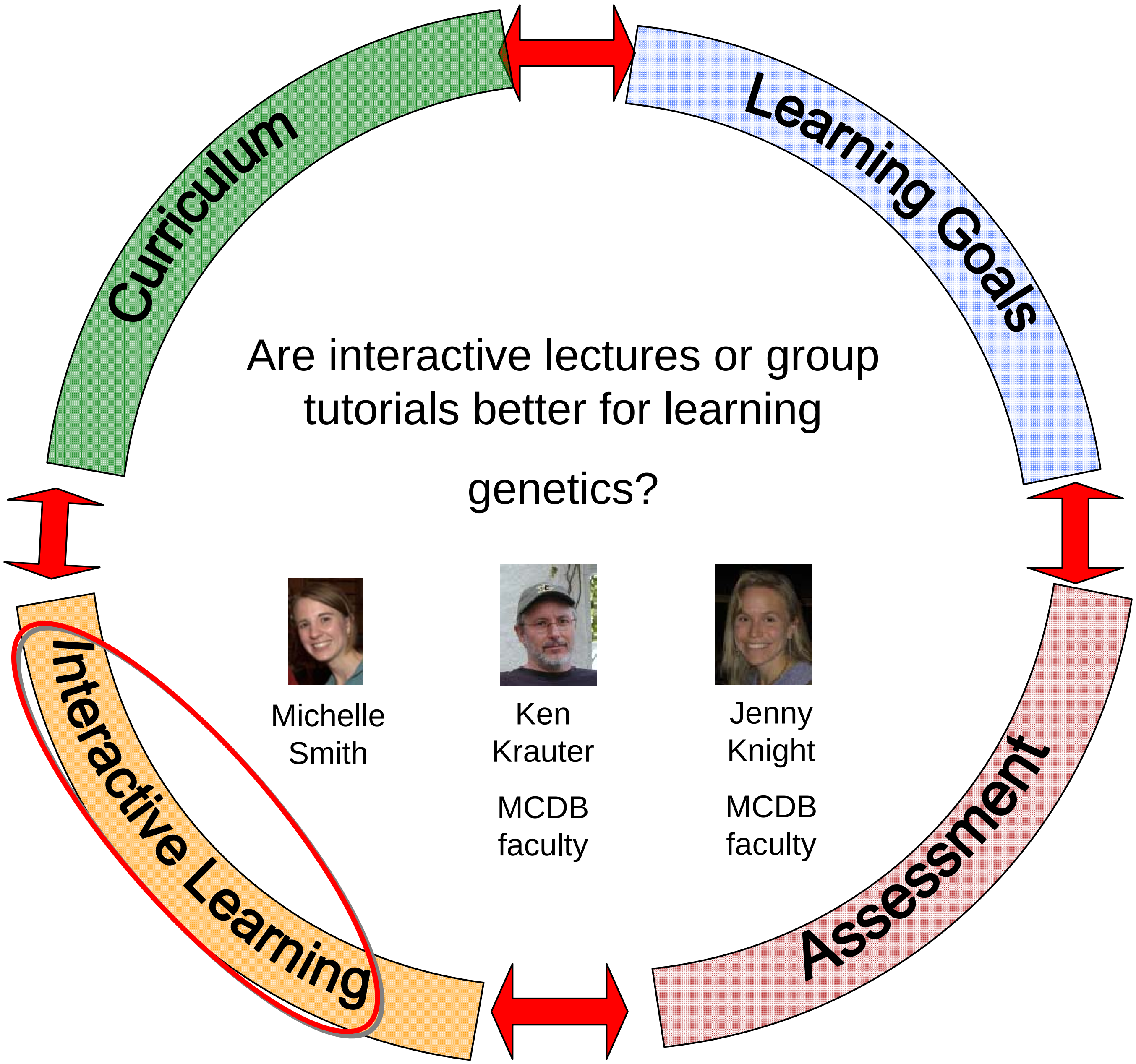
- Is expert-thinking the same across biology subdisciplines?

- Does thinking differ between academic and medical experts (university researchers & MDs)? *In collaboration with Pawel Kindler at UBC*

- Is student-thinking the same across subdisciplines or among populations with different career goals?

- Does student-thinking differ between introductory and upper division levels?

- Do we select for expert-like thinkers or develop expert-like thinkers?

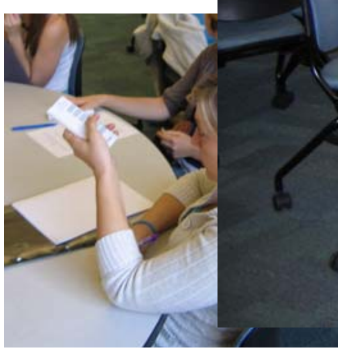

Curriculum
Learning Goals
Are interactive lectures or group tutorials better for learning genetics?
Michelle Smith
Ken Krauter
MCDB faculty
Jenny Knight
MCDB faculty
Interactive Learning
Assessment

Experimental Design

<u>Monday and Wednesday</u>: attend lectures in a traditional lecture hall and use clickers (~3 questions per class)

On Fridays 140 students are split two equal-sized groups

Interactive l



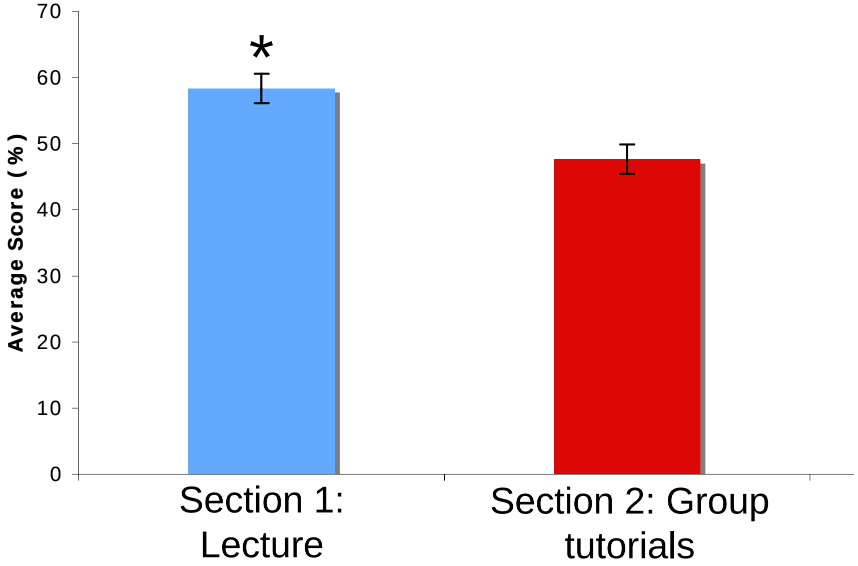
al activities

~8.5 clicker questions and ~1.5 general questions posed to the class

Facilitated by LAs, TAs and instructors

Student performance is equivalent in both groups

<u>Monitor learning that day:</u> At the end of each session there is a clicker quiz

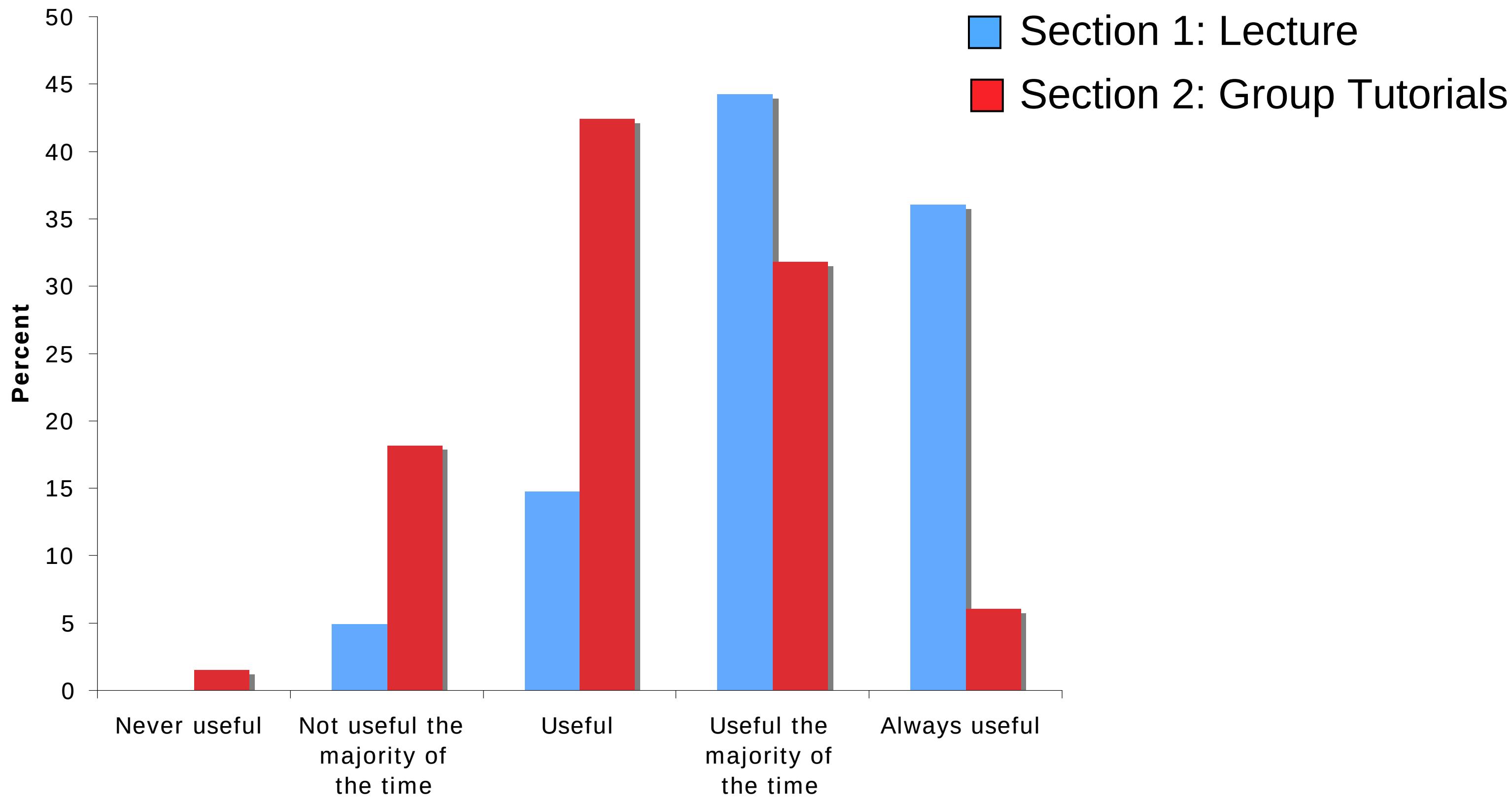


p<0.05

No significant differences: Homework grades and Exam scores

Students find the lectures more useful

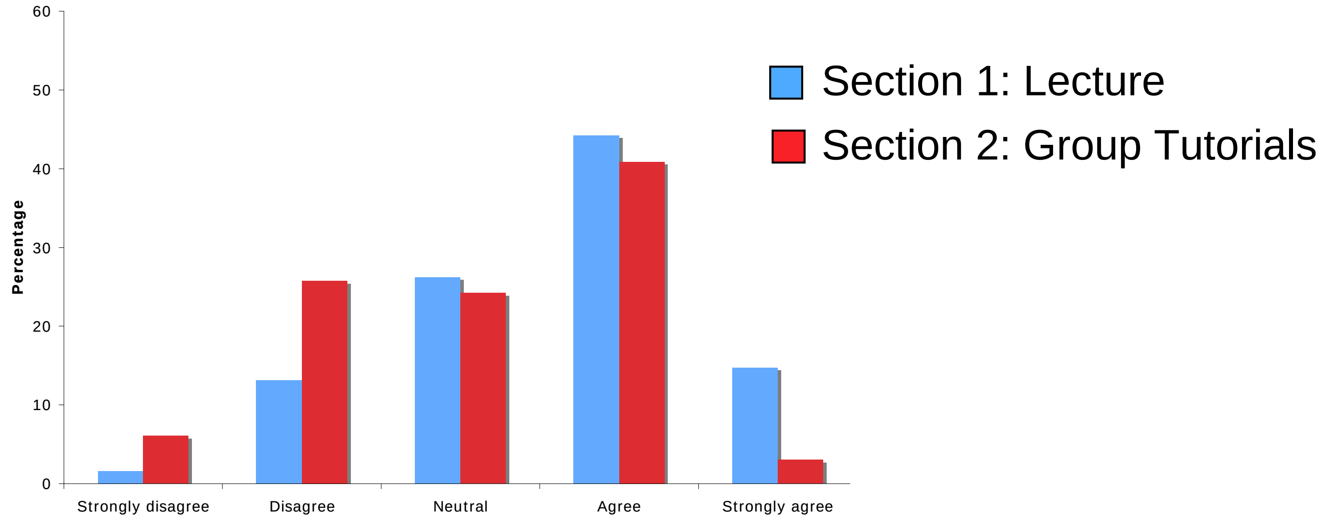
How useful are the Friday **lectures/ group activities** in helping you learn the course material?



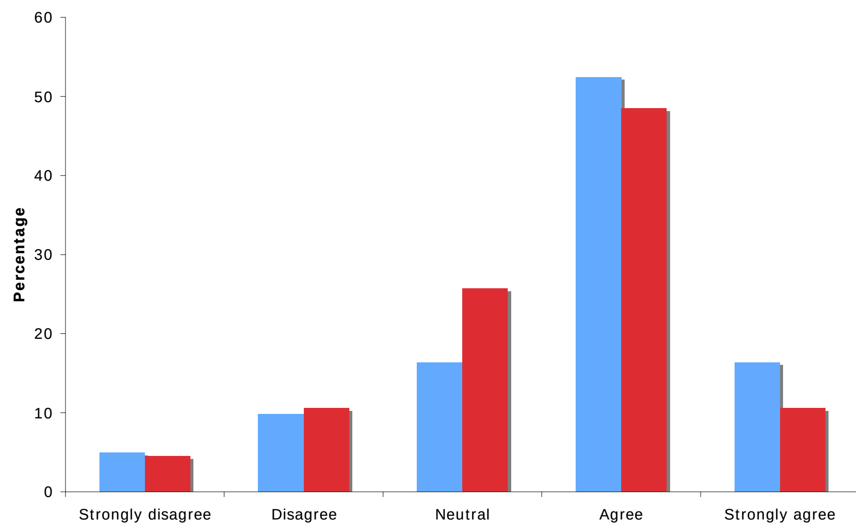
Significant difference between groups $p<0.05$, $\chi^2=26.18$

Students confidence about learning the material similar in both groups

On Fridays when I walk out of class, I am confident that I understand the material



When I sat down to take the exam, I was confident that I understood the Friday material



Future directions for the interactive learning experiment

• Determine if there are differences in retention between the two groups

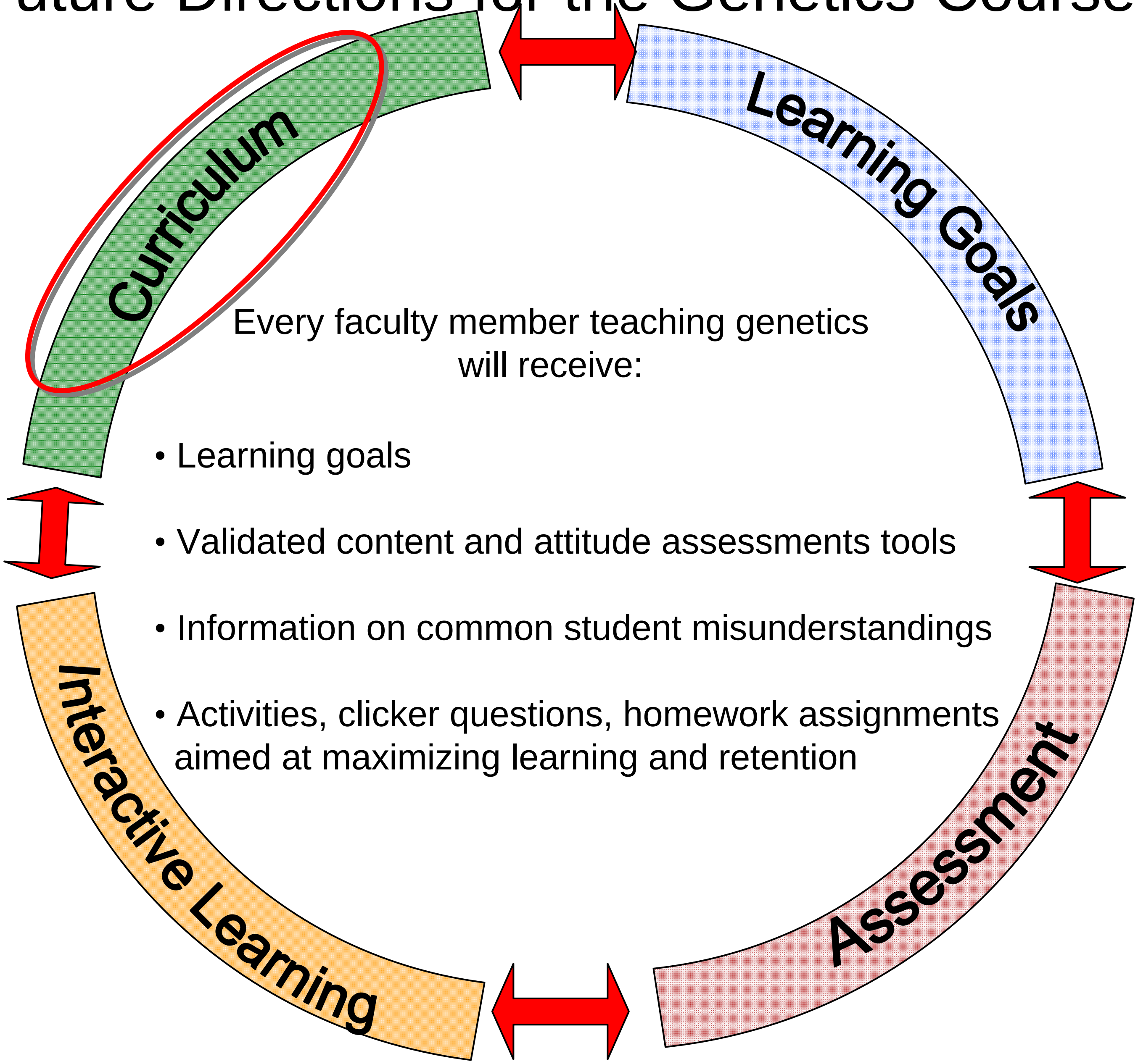
Final
Exam

Compare scores on questions that address topics covered in the first or second half of the semester

Next semester students will be asked to answer genetics questions on line

• Measure innovation in problem solving

Future Directions for the Genetics Course



Every faculty member teaching genetics will receive:

- Learning goals
- Validated content and attitude assessments tools
- Information on common student misunderstandings
- Activities, clicker questions, homework assignments aimed at maximizing learning and retention

Many thanks to….

SEI at CU-Boulder
Kathy Perkins
Carl Wieman
Science Teaching Fellows

MCDB SEI Coordinators
Jenny Knight
Bill Wood

MCDB faculty participating in the SEI
Corrie Detweiler
Christy Fillman
Nancy Guild
Michael Klymkowsky
Ken Krauter
Jennifer Martin
Joy Power
Jia Shi
Ravinder Singh
Quentin Vicens
Mark Winey

Bio-CLASS
Mindy Gratny
Angela Jardine
Kate Semsar

Georgetown University
Ronda Rolfes

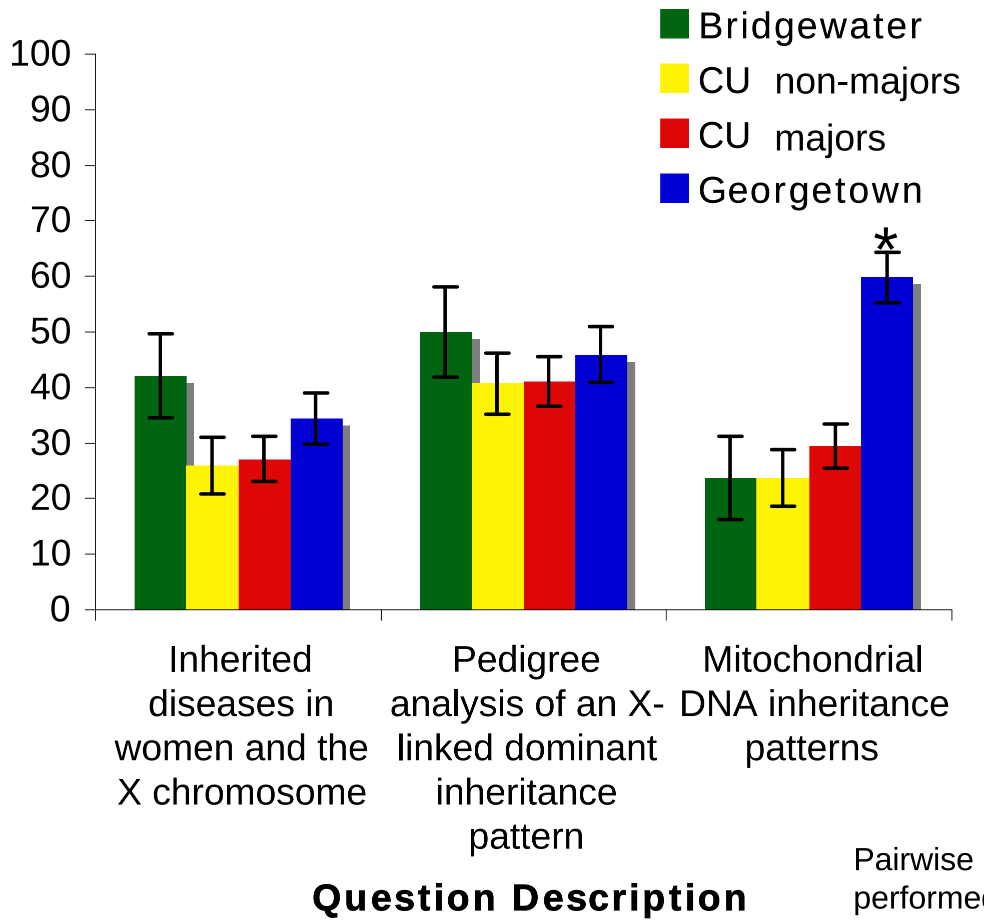
Bridgewater College
Robyn Puffenbarger

Undergraduate Learning Assistants
Jason Barr
Amy Doubet
Becca Green
Jolene Hammond
Tyler Long
Lauren Snella
Jill Terry

THE GENETICS STUDENTS!!!!

Example of wide-spread student conceptual problems

Learning goal: Analyze phenotypic data and deduce modes of inheritance from family histories.



Pairwise comparisons between means were performed with a Tukey post-hoc test (significance level set at $p<0.05$).

Most common conceptual problems on this learning goal

Many students think that:

1). An inherited disease that primarily affects women and not men is likely to be caused by a mutation on the X chromosome.

2). X-linked dominant inheritance patterns cannot be distinguished from autosomal recessive and X-linked recessive inheritance patterns.

3). Mitochondrial DNA is inherited in the same way as nuclear DNA.

4). Women pass on mitochondrial DNA only to women.