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# Using Clickers to Engage Groups in Collaborative Problem Solving and Inform Cognitive Tutor Development

## 1. Project Motivation

Consider strengths of Clicker-Based Activities and Cognitive Tutors:

### Benefits of clicker-based problem-solving activities (CBAs):

1. Cost-effective, and fairly easy to develop
2. Collaborative, hi-bandwidth discussion, range of questions, follow-up
3. Students are immediately accountable and their actions are visible to the instructor.

### Benefits of cognitive tutor based activities (CTs):

1. Individualized, step-by-step assistance
2. Ease of delivery to a larger audience

How might CBAs and CTs be combined to complement each other?

## 2. Project Design

### 1. Engage a class in complex genetic scientific problem solving.

- Introduce CBA leading step-by-step scientific reasoning (similar to a CT).
- Multiple choice CBA analogous to pull-down menus in PS steps in a CT.

### 2. Take a large step toward developing CT for the same material.

(If the activity design remains same, the main work needed to convert the CBA to a CT is the design of hint text for steps in each problem).

### 3. Lay foundation for research into a novel way to introduce problem solving.

as in-class CBA, to deepen subsequent student learning with a CT.

## 3. Clicker-Based Activities (CBAs) for Genetics

### Identify Key Skills in Advanced Domains: Cancer & Developmental Genetics.

- Cancer: Mechanisms by which a Cell Escapes Normal Control
- Development: Processes by which 1 Cell becomes Functioning Organism.

### Genetic Problem Solving Employs Two Types of Reasoning:

1. Process Modeling ("forward" from cause-to-effect)
  - start with underlying properties, infer observable results
2. Abductive Reasoning from Data ("backward" from effect-to-cause)
  - start with observations/data, reasons to properties leading to them (e.g., whether a mutation influencing a trait is dominant or recessive).

## 4. Project Deployment and Evaluation

### Deployment:

1. The instructor led a lecture and clicker-based activity (video-recorded).
2. Preceded by a pre-test of concepts & problem solving skills.
3. Following CBA, administer analogous post-test.
4. Long-term learning assessed using final exam.

### Results/Lessons Learned:

1. Informed development of CT Lessons (under NSF REAL grant) (see below)
2. Students learned shallow knowledge that reduced performance on earlier problem solving (epistasis in assembly/substrate pathways, vs. new concepts introducing epistasis in signaling pathways)
3. Final Exam performance very similar to previous year:
  - o Performance on both years high - Possible ceiling effects?
  - o Anticipate noise in in-vivo experiments in learning interventions (3 week lag until final)
  - o Use more immediate comparisons for learning gains, or increase difficulty of exam questions?

3. The regulatory pathway below includes 6 genes that together determine the presence of legs in drosophila. During development either of two start states determine which pathway genes are On or Off:  
High levels of LBC activates the gene 1. Low levels of LBC fails to activate (inhibits) gene 1.  
Your task is to indicate whether each gene is On or Off in this pathway under the conditions shown in each row of the table below. Each menu has six entries:  
'on' - The gene product is active, given the start state and normal pathway function.  
'off' - The gene product is inactive, given the start state and normal pathway function.  
'ON!' - The gene product is permanently active as a result of a mutation.  
'OFF!' - The gene product is permanently inactive as a result of a mutation.  
'LoF' - The gene has a loss-of-function mutation.  
'GoF' - The gene has a gain-of-function mutation.  
In the blue box to the right, fill in the final phenotype (Legs, No Legs) resulting from each of the conditions, and indicate whether the wing phenotype is normally promoted (ON) or inhibited (OFF) by each start state or combination of start state and Gene 3 mutation.

1. For each genotype/mutation at the left, explain the impact on the pathway below, and determine the resulting phenotype.

Here is a Network Representation of the steps in the pathway described above.

Gene-1 --> Gene-2 --| Gene-3 --> Gene-4 --| Gene-5 --> Gene-6 --> Phenotype

Genotype/Mutation	Pathway Perturbation due to the Given Genotype/Mutation	Phenotype	Does the mutated gene normally promote or inhibit phenotype?
High LBC, Gene-5 LoF	on --> on --  off --> off --  LoF --> OFF!	Legless	Gene-5 normally promotes phenotype.
Low LBC, Gene-1 LoF	LoF --> OFF! --  ON! --> ON! --  OFF! --> OFF!	Legless	Gene-1 normally promotes phenotype.
Low LBC, Gene-3 LoF	off --> off --  LoF --> OFF! --  ON! --> ON!	Legs	Gene-3 normally inhibits phenotype.

When normally functioning, all three genes with LOFs activate the next gene action in the pathway.  
Why do genes 1 and 5 promote the final phenotype but 3 does not?  
Gene 3 has a single downstream inhibition link.

CT Lesson: Process Modeling Activity for Developmental Genetics

The following data are from *C. elegans*. Use the epistatic data to inform your knowledge of a developmental pathway. No Vulva means: no normal vulval structures develop. Multi-Vulva means: multiple vulval structures develop.  
(note: LoF = loss of function GoF = gain of function += wild type)

Single Mutant Genotype	Phenotype
A LoF / A LoF	multi-vulva
A GoF / A +	no vulva
C LoF / C LoF	multi-vulva
D GoF / D+	multi-vulva
D LoF / D LoF	no vulva
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1. For each gene indicate whether the wild-type function promotes or inhibits vulval development:

Gene A	inhibits	vulval development
Gene C	inhibits	vulval development
Gene D	activates	vulval development

2. Choose a double mutant you would like to observe. From the resulting phenotype, indicate the epistatic gene and the gene order. (Draw any conclusions you can about gene order from each double mutant before going on to the next)

Double Mutant Genotype	Phenotype	Pair Order	Global Order
A LoF / D LoF	=> no vulva	D is epistatic => A < D	A < D
C LoF / D LoF	=> no vulva	D is epistatic => C < D	A < D & C < D
A GoF / C LoF	=> no vulva	A is epistatic => C < A	C < A < D

3. Using the results in parts 1 and 2, fill in the pathway diagram to generate a likely model for these genes:

Vulva Signal --| C --> A --| D --> Vulval Development

CT Lesson: Abductive Reasoning Activity for Developmental Genetics



The CMU Genetics Cognitive Tutor

<http://www.cs.cmu.edu/~genetics/>

