StarGenetics – Implementation, evaluation, outreach, & development

Education Group Meeting
March 11, 2011

Lourdes Alemán, Ph.D.
Stacie Bumgarner, Ph.D.

The Education Group of the MIT Department of Biology

star Software Tools for Academics & Researchers
Upcoming events....

http://educationgroup.mit.edu
Seminars

HHMI Professor Rich Losick

**Topic:** Long-Term, Hands-on Research Experiences Engage Students from Diverse Backgrounds

**Date & Time/Location:** Friday, April 15th @ 2:00 pm/Whitehead Auditorium

Professor Mike Klymkowsky

**Topic:** Bioliteracy and the BCI (Biology Concept Inventory)

**Date & Time/Location:** Friday, April 22 @ 2:30 pm/Whitehead Auditorium

Dr. Laura Border

**Topic:** The Graduate Teacher Program – Synergy between teaching & science

**Date & Time/Location:** Wednesday, May 25th @ 2:30 pm/66-110
Seminars

HHMI Professor Rich Losick

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**Date & Time/Location:** Wednesday, May 25th @ 2:30 pm/Whitehead Auditorium

Sign up sheet: Lunch w/ speakers
Education Group Meeting

Dr. Ishara Mills-Henry

**Topic:** Science of the Eye Outreach Program (Jon King)

**Date & Time/Location:** Thursday, April 7th @ 3:00 pm/ 68-180
Education Group Meetings

Dr. Ishara Mills-Henry

Topic: Science of the Eye Outreach Program (Jon King)

Date & Time/Location: Thursday, April 7th @ 3:00 pm/ 68-180

Sign up sheet: Ed Group meetings participants
Help build DNA LEGO molecules sets for Boston Public Schools

Dr. Kathy Vandiver/Dr. Amanda Gruhl (CEHS/MIT Museum/Edgerton Center)

See Movie1: DNA LEGO molecule sets
Help build DNA LEGO molecules sets for Boston Public Schools

Dr. Kathy Vandiver/Dr. Amanda Gruhl

Date & Time: Monday, March 21st @ 6 – 9 pm

Location: 56-202 (CEHS conference room)

Sign up sheet: Volunteers!
star
Software Tools for Academics & Researchers

Biology tools

http://web.mit.edu/star/
STAR biology tools

- **StarBiochem:** protein 3D viewer

- **StarGenetics:** virtual genetics laboratory

- **StarORF:** gene finger (six frame translator)
Design process of STAR tools

StarBiochem

Professor: Graham Walker
OEIT: Chuck Shubert
Introductory Biology Series (7.01X)

StarGenetics/StarORF

Professor: Chris Kaiser
OEIT: Ivan Ceraj
Introductory Biology Series (7.01X)
Genetics
Summer Pre-graduate Bridge Program
What **we** did to make tools more accessible to others and increase usage

- Create curriculum modules
- Conduct teacher/faculty training workshops
- Design and implement outreach activities
- Collaborate with wide range of educational institutions
- Assess how software tools impact students’ learning experience
- Presented at scientific meetings and educational technology conferences
- Advertised through mail campaign and Google AdWords
STAR tools usage from 2007-2010

Number of users:

- StarBiochem
- Star Biology Tools

Years:
- 2007
- 2008
- 2009
- 2010

Usage:
- 2007: Low usage
- 2008: Increase in usage
- 2009: Significant increase in usage
- 2010: Highest usage
What IS StarGenetics?

**StarGenetics**: A virtual genetics laboratory

**Developers:**
- **Faculty**: Professor Chris Kaiser
- **Biology Education Group**: Lourdes Alemán, Stacie Bumgarner
- **OEIT-STAR**: Ivan Ceraj

**Educational Goal:**
To teach genetic concepts, experimental design & data interpretation
WHY was StarGenetics developed?
Limitations of traditional methods for teaching genetics concepts

Typical genetics problem:

- Provides:
  - Experiment
  - Data

- Asks for:
  - Analysis/
  - Conclusions
Limitations of traditional methods for teaching genetics concepts

Typical genetics problem:

- Provides:
  - Experiment
  - Data

- Asks for:
  - Analysis/Conclusions

What’s missing?
Limitations of traditional methods for teaching genetics concepts

Typical genetics problem:

- Provides:
  - Experiment
  - Data

- Asks for:
  - Analysis/Conclusions

What's missing?

Doesn't teach students how to develop and test a hypothesis!
Teaching genetics in a real genetics lab is ideal, but is not always an option...

**Cost**
Establishing a genetics lab can be costly ($10,000 - $50,000).

**Time**
Genetics experiments can take longer than the time available to explore a concept.

**Course design**
Not all genetic courses offer a lab component.
Virtual genetic cross simulator → **StarGenetics**

- Freely accessible: [http://web.mit.edu/star/genetics/](http://web.mit.edu/star/genetics/)
- Platform independent (Windows, Mac, Unix/Linux)
- Simulates actual experimental process
- Address cost and time issues associated with traditional genetic labs
- Allows for in-class demos & new dimension to homeworks
StarGenetics Fruit Fly Visualizer

Let’s Take a Quick Tour!
See Movie2: StarGenetics Fly Tour
StarGenetics allows for easy customization of exercises

**Source Files = Encryptable Excel Workbooks**

<table>
<thead>
<tr>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td><strong>Introduction</strong></td>
</tr>
<tr>
<td><strong>1.</strong> StarGenetics exercises are developed in Excel. You can modify this Excel Workbook to develop your own StarGenetics exercise.</td>
</tr>
<tr>
<td><strong>2.</strong> This Excel Workbook contains 5 additional tabs:</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>9</td>
</tr>
<tr>
<td><strong>- Mating Engine:</strong> this tab specifies the type of visualizer used within the software and its specific characteristics.</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td><strong>- Genes &amp; Alleles:</strong> this tab specifies the alleles and genes in question and their location within the genome.</td>
</tr>
<tr>
<td>11</td>
</tr>
<tr>
<td><strong>- Genes Interaction:</strong> this tab defines the relationship between genotypes and phenotypes.</td>
</tr>
<tr>
<td>12</td>
</tr>
<tr>
<td><strong>- Gel:</strong> this tab specifies the size of the DNA markers used in the exercise.</td>
</tr>
<tr>
<td>13</td>
</tr>
<tr>
<td><strong>- Organisms for mating:</strong> this tab defines the organisms presented by StarGenetics to the users.</td>
</tr>
<tr>
<td>14</td>
</tr>
<tr>
<td><strong>3.</strong> StarGenetics can open any properly formatted exercise that has been developed in Excel like this one (for ex: StarGenetics will open this exact Excel file as is).</td>
</tr>
<tr>
<td><strong>However, encrypting them is recommended so that users do not have access to the information. You can then provide the encrypted version to your users for them to open in StarGen</strong></td>
</tr>
<tr>
<td><strong>To convert an Excel file into an encrypted SGZ format, click on ‘Tools -&gt; SGZ encryptor’ and follow the instructions.</strong></td>
</tr>
<tr>
<td><strong>For further information on StarGenetics go to:</strong> <a href="http://web.mit.edu/star/genetics/">http://web.mit.edu/star/genetics/</a></td>
</tr>
</tbody>
</table>
Modifiable characteristics in StarGenetics Fly

**organism characteristics**
progeny per cross, # of matings per organism, recombination rates for X & Y

genotypes & corresponding phenotypes
fly: 6 visible phenotypes, 1 nonvisible phenotype

genes interactions
epistatic relationships, linkage

organisms
define which organisms will be available in Strains window
Concepts that can be taught using StarGenetics

**genetic concepts**
- modes of inheritance
  - genotype → phenotype
  - dominant vs. recessive alleles
  - allele series (>2 alleles)
  - multiple phenotypes
  - autosomal vs. sex-linkage

**gene interactions**
- epistasis
- linked genes
- complementation

**genetic tools**
- genetic crosses
  (P/F1/F2; testcross, backcross; dihybrid cross; reciprocal etc.)
- chi square analysis
- punnett squares
Unique visits: 12,241
Countries: 110
Cities: 1,391
Talk Overview:

- Implementing StarGenetics at Suffolk University – Trying out StarGenetics in a variety of educational activities

- Pilot study to evaluate learning outcomes – So much to learn about how to study learning outcomes!

- Outreach efforts
  Spreading the word and supporting others

- Further development
  Additional software, more curriculum
Implementing StarGenetics at Suffolk University

Classical Genetics Lecture & Laboratory

**Fall 2008** – Prior to StarGenetics Implementation

**Fall 2009** – Full implementation of StarGenetics

- **Small class size (~20)**
  - Intro course conducted like a seminar
  - Knew all of my students

- **Limited resources**
  - Had a laboratory component, but not well resourced
  - Lots of contamination, fly death, student frustration

- **Heterogeneous student population**
  - Preparation, ability?, interest, departmental culture
Implementing StarGenetics at Suffolk University

Trying out StarGenetics in a variety of educational activities...

- **Lecture demos**
  - Effect of sample size and deviations due to chance
  - Genetic linkage

- **Dry laboratory fly exercise**
  - To help prepare students for wet lab fly exercise
  - Enrich their learning experience, given obstacles

- **Homeworks**
  - 1 to 2 weeks to work on each; increased in complexity
  - Added dimension: Experimental thinking
Implementing StarGenetics at Suffolk University

StarGenetics Lecture Demo: Why deviations due to chance?

How we typically introduce deviations due to chance...

\[ P \times F_1 \rightarrow F_2 \]

Selfing of \( F_1 \)s

6022 yellow : 2001 green

*Approximately* 3 : 1
Implementing StarGenetics at Suffolk University

**StarGenetics** Lecture Demo: Why deviations due to chance?

How we typically introduce deviations due to chance...

- The **SIZE** of an experimental population (**the sample size**) is an important component of statistical significance.

- The larger the sample size, the closer observed percentages can be expected to match values predicted by an experimental hypothesis, if that hypothesis is correct.
Implementing StarGenetics at Suffolk University

**StarGenetics** Lecture Demo: Why deviations due to chance?

Intuitive demonstrations with non-genetic examples…

Hypothesis..................This is a fair coin.

Results expected..........Heads 50%, Tails 50%

Suppose we flip this coin 10 times:

And observe: 4 heads : 6 tails

Do the observed results fit the hypothesis? Yes

1000 times:

400 heads : 600 tails

Even though the ratio (2:3) is exactly the same!
Examples can be GENETIC! And can then perform statistical analysis...

When observing SMALL numbers of progeny, we sometimes observe deviations from the expected ratio due to chance... Expects 3 WT : 1 ebony
Observe 4 WT : 1 ebony

But as the sample size of F₂ progeny grows LARGER, deviation from the expected ratio is diminished if hypothesis is correct... Expects 3 WT : 1 ebony
Observe 3 WT : 1 ebony
Implementing StarGenetics at Suffolk University

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The farther apart two genes are located from one another on the same chromosome, the more likely their alleles are to be separated from one another by recombination during meiosis.

Genes located close together on the same chromosome assort together with a frequency that depends on the distance between them.
StarGenetics Lecture Demo: Why Linkage?

Often text-based examples are presented:

“You obtain the following testcross progeny...”

<table>
<thead>
<tr>
<th>Trait Description</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown body, Red eyes</td>
<td>35</td>
</tr>
<tr>
<td>Brown body, White eyes</td>
<td>14</td>
</tr>
<tr>
<td>Yellow body, Red eyes</td>
<td>17</td>
</tr>
<tr>
<td>Yellow body, White eyes</td>
<td>34</td>
</tr>
</tbody>
</table>

Total: 100
StarGenetics Lecture Demo: Why Linkage?

Often text-based examples are presented:

“You obtain the following testcross progeny...”

<table>
<thead>
<tr>
<th>genotype</th>
<th>count</th>
</tr>
</thead>
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<td>Brown body, Red eyes</td>
<td>35</td>
</tr>
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</tbody>
</table>

Total: 100 Parental types
StarGenetics Lecture Demo: Why Linkage?

Often text-based examples are presented:

“You obtain the following testcross progeny…”

<table>
<thead>
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Implementing StarGenetics at Suffolk University

**StarGenetics Lecture Demo: Why Linkage?**

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<td>Recombinant types</td>
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</tr>
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<td>Parental types</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Recombination Frequency (RF):**

\[
\text{Recombination Frequency (RF)} = \frac{\# \text{ of Recombinants}}{\# \text{ of Total Progeny}} \times 100
\]

1% RF = 1 unit of measure along a chromosome

= 1 centimorgan (cM)

= 1 map unit (m.u.)
Implementing StarGenetics at Suffolk University

**StarGenetics** Lecture Demo: Why Linkage?

Often text-based examples are presented:

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<td></td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>100</strong></td>
<td></td>
</tr>
</tbody>
</table>

When genes are unlinked, Parentals = Recombinants

50% 50%

Linkage is defined as Parentals > Recombinants
We thought that this information might seem very abstract to many students....

... and we wondered if we could more richly support the concept of gene linkage using StarGenetics in a concept demo.

... A visual real-time demonstration of gene linkage!!
See Movie3: StarGenetics Linkage Demo
**Implementing StarGenetics at Suffolk University**

**StarGenetics** Lecture Demo: Linkage!

Custom Source file constructed using Excel Template on website...
http://web.mit.edu/star/genetics/problemsets/development/index.html

On the “Genes & Alleles” Tab in Excel Source File:

<table>
<thead>
<tr>
<th>Alleles</th>
<th>Gene</th>
<th>Chromosome</th>
<th>Gene Location</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>G, g</td>
<td>Green eyes</td>
<td>2</td>
<td>1</td>
<td>recessive</td>
</tr>
<tr>
<td>Y3, y3</td>
<td>Yellow body</td>
<td>2</td>
<td>5</td>
<td>recessive</td>
</tr>
<tr>
<td>Y2, y2</td>
<td>Yellow body</td>
<td>2</td>
<td>30</td>
<td>recessive</td>
</tr>
<tr>
<td>Y1, y1</td>
<td>Yellow body</td>
<td>2</td>
<td>50</td>
<td>recessive</td>
</tr>
</tbody>
</table>
Implementing StarGenetics at Suffolk University

Trying out StarGenetics in a variety of educational activities...

- **Lecture demos**
  - Effect of sample size and chi square tests
  - Genetic linkage

- **Dry laboratory fly exercise**
  - To help prepare students for wet lab fly exercise
  - Enrich their learning experience, given obstacles

- **Homeworks**
  - 1 to 2 weeks to work on each; increased in complexity
  - Added dimension: Experimental thinking
Implementing StarGenetics at Suffolk University

**StarGenetics** Dry Laboratory: Fly lab simulation

**In preparation for live fly cross experiment:**
- familiarize with modes of inheritance in active learning exercise
- improve interpretation of data collected from actual fly crosses

Given 4 StarGenetics source files containing WT flies + mutant flies:

1. Autosomal recessive
2. Autosomal dominant
3. X-linked recessive
4. X-linked dominant
Implementing StarGenetics at Suffolk University

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Implementing StarGenetics at Suffolk University

**StarGenetics** Homeworks:

- **Started with simple concepts**
  - Students need time to get familiar with the software
  - Builds confidence

- **Increased complexity over time**
  - Followed increasing complexity of course curriculum
  - Limit matings
  - Limit provided flies (so students generate flies they need)

- **Versions of homeworks used now available on website**
  
See Movie4: StarGenetics Homework Sample 1
Talk Overview:

- **Implementing StarGenetics at Suffolk University** –
  Trying out StarGenetics in a variety of educational activities

- **Pilot study to evaluate learning outcomes** –
  So much to learn about how to study learning outcomes!

- **Outreach efforts**
  Spreading the word and supporting others

- **Further development**
  Additional software, more curriculum
Pilot Study to Evaluate Learning Outcomes

How effective is StarGenetics in supporting student learning?

Student Survey Results...

Learning specific Skills & Concepts

- Problem-solving skills
- Parental, F1, F2 generations
- Dominant vs. recessive traits
- Deviations due to chance; Chi square
- Independent assortment vs. Linkage
- Autosomal vs. X-linkage
- Epistasis

Scale:
- Not at all
- Minimal
- Moderate
- Considerable
- Very great
Pilot Study to Evaluate Learning Outcomes

How effective is StarGenetics in supporting student learning?

Student Survey Results... Learning how to Design Experiments

- Design own experiments
- Identify appropriate flies to cross
- Determine flies needed to be generated
- Analyze genetic data
- Interpret experimental results
- Understand real fly cross experiments
- Analyze data from real fly cross experiments
It was easy to learn how to use StarGenetics.

StarGenetics was user-friendly.

The StarGenetics graphical interface provided an effective experience.

StarGenetics helped me learn key genetic concepts taught in class.

StarGenetics offered an effective learning experience.

StarGenetics was fun.

I would like other genetic concepts to be taught using StarGenetics.
Caveat of surveys...

- Rely on Self-reporting by Students
- Students often want to please you...

We wanted to go further with evaluation...
Challenges of evaluating educational outcomes...

- Our first time doing THIS kind of research...
- Different methodologies and analyses
- Small sample size (n < 20)
- Ethical considerations...
  - human subjects
  - students ≠ guinea pigs
  - cases versus controls
Helpful resources available!

- Existing vetted assessment tools
  - Go to [www.visionandchange.org](http://www.visionandchange.org) to download AAAS/NSF report:
    VISION AND CHANGE IN UNDERGRADUATE BIOLOGY EDUCATION: A CALL TO ACTION  (see page 25)

- MIT Teaching & Learning Lab
  - Dr. Lisa Shuler, Dr. Rudy Mitchell, Dr. Lori Breslow (Director)

- MIT COUHES & IRB
  - Ethics Training, Informed consent, Approval, etc.
Pilot Study to Evaluate Learning Outcomes

Choosing tools to use in our evaluation...

From Janet Batzli, Biology Core Curriculum, University of Wisconsin-Madison & Tammy Long, Plant Biology, Michigan State University
Tools used for evaluation of StarGenetics in Pilot Study

- Surveys
- Pre/Mid/Post Concept Quiz
  - BCI Assessment test (M. Klymkowsky & K. Garvin-Doxas)
- Open-Ended Exam Questions
  - Assess ability to design experiments appropriate to answer a given question
- Rubric-based comparison of formal lab reports
  - Before & after StarGenetics implementation
Pilot Study to Evaluate Learning Outcomes

Tools used for evaluation of StarGenetics in Pilot Study

BCI Assessment test (M. Klymkowsky & K. Garvin-Doxas)

- > 18,000 student responses to 69 open-ended, short essay questions
- Responses analyzed with Ed’s Tools system (http://edstools.colorado.edu) to identify response categories & student language
- Researchers used responses to generate “think-aloud” interview protocols
- ~20 students were interviewed “in depth”
- Lead to construction of multiple-choice questions with distractors
- Follow-up interviews conducted for validation
- Piloted in a number of University biology classes across country
Tools used for evaluation of StarGenetics in Pilot Study

- **Surveys**

- **Pre/Mid/Post Concept Quiz**
  - BCI Assessment test (M. Klymkowsky & K. Garvin-Doxas)

- **Open-Ended Exam Questions**
  - Assess ability to design experiments appropriate to answer a given question

- **Rubric-based comparison of formal lab reports**
  - Before & after StarGenetics implementation
Pilot Study to Evaluate Learning Outcomes

How effective is StarGenetics in supporting student learning?

A work in progress...  (analogous to a lab meeting!)

- Now in process of analyzing collected data
- Plan to share results here and in publication
- Much learned from experience with pilot study
- Better prepared for larger study
  - MIT faculty open to evaluations in their courses
Talk Overview:

- Implementing StarGenetics at Suffolk University –
  Trying out StarGenetics in a variety of educational activities

- Pilot study to evaluate learning outcomes –
  So much to learn about how to study learning outcomes!

- Outreach efforts
  Spreading the word and supporting others

- Further development
  Additional software, more curriculum
Outreach: A critical component of Education Innovation

Without active outreach, many education initiatives die at the site of local innovation.


Outreach Efforts

Example Users:

- **Undergraduate college students**
  - Introductory Biology (MIT, Tufts, Howard University)
  - Introductory Genetics (MIT, Suffolk University)
  - University Outreach Programs (MIT Quantitative Biology WS, MIT Summer Bridge Program)

- **High school students**
  - Medford HS & Monument HS (Boston Public Schools)
  - Teacher training programs (Boston Public Schools)
  - High School Outreach Programs (Broad Institute)
  - High School Fieldtrips (MIT Biology Department)
Outreach Efforts

**Workshops & Demos for faculty, instructors, & TAs:**

E.g., Howard University, University of Colorado, Roxbury Community College, Florida International University, MIT QBW2011, Brazilian Santander Universities and CERTI, MIT-Haiti Initiative, JFY Networks, Whitehead Teacher Partners

**Support for remote users:** star@mit.edu

E.g., University of Chicago, Colchester High School (VT), New College of Florida, Pacific Lutheran University (WA)

**Focus groups:**

E.g., High School Teachers (Whitehead Teacher Partners)
Talk Overview:

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Further development

StarGenetics visualizers

Currently Available:

- Flies
- Yeast

In progress:

- Mendel’s Peas (Summer 2011)
- Bacteria (2011-2012)

plus:
- Smileys
- Lego fish
StarGenetics genetic cross simulator: Yeast
See Movie6: StarGenetics Yeast Tour
Further development

http://web.mit.edu/star/genetics/documentation/index.html

User Manual: Learn more about StarGenetics Yeast!
StarGenetics genetic cross simulator: Smileys
StarGenetics genetic cross simulator: Lego Fish

Punnett Square

Parental Genotype 1:
- AA
- Aa
- aa

Parental Genotype 2:
- AA
- Aa
- aa

Punnett square table:

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>a</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
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*plus:*
Smileys & Lego fish
Acknowledgements

Star Team
Chuck Shubert
Lourdes Aleman
Sara Bonner
Stacie Bumgarner
Rocklyn Clarke
Ivan Ceraj
Justin Riley

Biology Department
Graham Walker
Chris Kaiser
Diviya Sinha
Judy Carlin

OEIT
Vijay Kumar
Molly Ruggles
Toru Iiyoshi
Violeta Ivanova
Jim Cain
Judy Leornard
Mary Curtin

Collaborators
Melissa Kosinski-Collins
Megan Rokop
Kathy Vandiver

Outside Funding
HHMI
Davis Educational Foundation

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