Inquiry-based Learning: The Student-centered Classroom

Francis Molina – Science Education Consultant, University of Colorado
This workshop is informed by work at the following institutions:

**U.S.A.**

- American Association for the Advancement of Science (AAAS)
- National Research council, NAS
- Northwestern University
- University of Colorado

**France**

Fondation La main à la pâte
1. Ways to improve science teaching and student learning
2. Inquiry-based learning and the student-centered classroom
3. Storyline approach to curriculum development
4. Example Genetics lesson that makes use of inquiry in a student-centered classroom
5. Using (student) discussions for active learning
6. Questions & Ideas for Future Work
Conceptual Understanding: The Holy Grail of Science Education

How do we know that they know?

1. Can explain in their own words.

2. Can connect to other science ideas.

3. Can apply knowledge in new situations.
How can we help students learn?

No more rote “learning” or memorization!

Rote learning is reinforced by “teaching by telling” methods.
Improving Teaching and Helping Students Learn

1. Align curriculum, instruction, assessment, and teacher training to the same set of clearly articulated performance expectations (PEs).

2. Integrate Science & Engineering Practices and Crosscutting concepts into teaching of content.

3. Let students do the heavy lifting and engage in active learning.
1. Align all aspects of education to PEs

- Curriculum
- Instruction
- Assessment
- Teacher Training
2. Integrate Science & Engineering Practices and Crosscutting concepts into teaching of content.

**Practices for K-12 Science Classrooms** *(Source: NGSS)*

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information
Crosscutting Scientific and Engineering Concepts
(Source: Next Generation Science Standards [NGSS])

1. Patterns
2. Cause and effect: Mechanism and explanation
3. Scale, proportion, and quantity
4. Systems and system models
5. Energy and matter: Flows, cycles, and conservation
6. Structure and function
7. Stability and change
Matter and Energy in Organisms and Ecosystems (HS)

Use a model to illustrate that **cellular respiration** is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed, resulting in a net transfer of energy.

**Science & Engineering Practice:** Developing and using models

**Disciplinary Core Idea:**
As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.

**Crosscutting Concept:**
Energy and Matter
3. Let Students do the Heavy Lifting

• We are NOT the source of all knowledge.

• No more “sage on the stage.”

• Put students in the driver’s seat.
What doesn’t work? Lectures.

“Students in classes with traditional stand-and-deliver lectures are 1.5 times more likely to fail than students in classes that use more stimulating, so-called active learning methods.”

-Freeman et al. (PNAS, 2014)
“Teaching approaches that turned students into active participants rather than passive listeners reduced failure rates and boosted scores on exams by almost one-half a standard deviation.”

-Freeman et al. (PNAS, 2014)

Example:
Having students clarify concepts to each other and reach a consensus on an issue.
Achieving an inquiry-driven, student-centered classroom

Not a trivial task:
- Takes months to develop just one unit!

Requires a paradigm shift:
- Teacher as the source of all knowledge
- Students engaging in active learning
Debriefing

Subject-area Leads Contribute their Group’s Two (2) descriptions of Student-centered classroom and Inquiry-based learning
Please share your thoughts

Student-centered classroom

What is Inquiry-based learning
Proposed Definitions

Student-centered Classroom

A student-centered classroom is based on autonomy and the elimination of traditional teaching practices. It operates on collaboration, project-based learning, technology integration, and plenty of conversation between students and teachers about learning.

→ **Students take the driver’s seat.**

Inquiry-based Learning

A process where students construct much of their understanding of the natural and human-designed worlds.

→ **Involvement that leads to understanding.**
20 mins

Curriculum Co-design and Storylining
Collaborative Curriculum Development: A Storyline Approach

Moore Project HS Genetics Storyline
Draft: 7/8/2016
Lesson Sequence Builder

**HS Genetics Unit:** How can science be used to our lives better?

<table>
<thead>
<tr>
<th>Targeted NGSS Performance Expectation(s):</th>
<th>Shifts in NGSS</th>
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<tbody>
<tr>
<td>HS-LS1-1: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells. [Assessment Boundary: Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemical synthesis.]</td>
<td>1. Organized around disciplinary core ideas (explanatory ideas)</td>
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<td></td>
<td>2. Central role of scientific practices</td>
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<td>3. Coherence: building and applying ideas across time.</td>
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<tr>
<td>HS-LS3-1: Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanisms of specific steps in the process.]</td>
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<tr>
<td>HS-LS3-2: Make and defend a claim based on evidence that it is possible to the role of genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. [Clarification statement: Emphasis is on using data to support arguments for the way variation occurs.] [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]</td>
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<td>HS-LS3-3: Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population. [Clarification Statement: Emphasis is on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.] [Assessment Boundary: Assessment does not include Hardy-Weinberg calculations);</td>
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<tr>
<th>Targeted Scientific Practice(s)</th>
<th>Targeted DCI(s)</th>
<th>Targeted Cross-Cutting Concept(s)</th>
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<tr>
<td><strong>Ask Questions and Defining Problems</strong>&lt;br&gt;Aking questions and defining problems in 9-12 builds on K-8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.</td>
<td>LS1.A, Structure and Function&lt;br&gt;All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins.</td>
<td>Cause and Effect&lt;br&gt;Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</td>
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Lesson 9: Can genetic disorders be cured?

HS Genetics Unit: How can science be used to our lives better?

Lesson 9: What we are doing now: Students are figuring out what genetic technologies exist and how they work in order to start addressing the driving question: “How can science be used to make our lives better?” and to think about the challenge: facilitating a discussion with parents and community members about the bioethics of genetic engineering technologies (GET).

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<th>Phenomena</th>
<th>Lesson Performance Expectation(s)</th>
<th>What We Figure Out</th>
<th>(CCDGs &amp; DCIs), New Questions and Next Steps</th>
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| L.9. Can genetic disorders be cured? (3 periods) | We are born with and maintain many of our genetic traits. People with MD have a gene that doesn’t properly make dystrophin. If the gene sequence could change in order to code for normal dystrophin, would that cure MD? | Obtain information to use as evidence to formulate an argument about the role of DNA and chromosomes to explain how genetic engineering technologies have cured or been used to treat genetic disorders. | We figure out that there is a wide variety of genetic engineering technologies (GET) that have been tried or are still in use over the past 100+ years. Some of those technologies include:  
- Selective breeding  
- Human eugenics  
- Recombinant DNA plasmids to make human insulin  
- Gene therapy - Jesse Gelsinger and Ashanti DeSilva cases  
- Cancer gene therapy for a brain tumor  
- Cloning  
- Golden rice, Bt corn, (transgenic organisms)  

We figured out that there are a lot of considerations to take into account when looking at phenomena of GET and considering whether people should be able to do or use those technologies.  

As we participated in this lesson, we worked with the cross-cutting concept of causality.  

We have a lot of questions!  
- What are the most current genetic engineering technologies?  
- Is there a GET that could cure people with genetic disorders like MD?  
- What would our parents or guardians have to say about GETs?  
- Is it right or wrong to change genes? Who will decide?  

We decide that next we should figure out what the most current GETs are and how they work. | **Next Lesson...Where we’re going** | In the next lessons, students explore one possible GET that holds promise for the future of accurate and efficient gene editing, CRISPR. |

NGSS PEs: HS-LS3-1 & HS-LS3-2
Generating Questions About the Phenomenon: Turning Students Into Active Participants

Four Discussion Types

1. **Posing and Prioritizing Questions Discussion**
   To *identify questions that students want to investigate*.

2. **Initial Ideas Discussion**
   To support students in *making tentative connections between questions being asked and the students’ experience*.

3. **Building Understandings Discussion**
   To provide the teacher and students with an opportunity to *clarify which understandings have been developed*.

4. **Consensus Building Discussion**
   To press toward *a common (class-level) explanation* or model, resolving (if possible) disagreements, or partial understandings.
Example: Initial Ideas Discussion

**Potential Talk Moves When Eliciting Initial Ideas:**

What are your ideas about how to explain this phenomenon?

What’s your “first draft” thinking about how to solve this design challenge?

Let’s see what we think about this phenomenon, using our own past experience as a guide and what we’ve learned in class this year.

What experiences do you have that might help you think about this phenomenon?
Lesson 10

Why are scientists so excited and apprehensive about a new technology?
Lesson 10: Why are scientists so excited and apprehensive about a new technology?

**HS Genetics Unit: How can science be used to make our lives better?**

**Previous Lesson:** Where we've been
In the last lesson students wrote complete explanation for how DMD works.

**This Lesson:** What we are doing now: Students will learn about CRISPR technology and why scientists are excited and worried about its potential uses.

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<td>L10. What is the most current genetic engineering technology? Why are scientists so excited—and apprehensive—about this new technology?</td>
<td>CRISPR was recently discovered and has scientists very excited and apprehensive about its potential uses.</td>
<td>Ask questions about the structure and function of CRISPR in bacteria to start explaining how CRISPR works and why it might work in all sorts of organisms.</td>
<td>We watch a video and listen to a radio clip about CRISPR, this new genetic engineering technology that's exciting biologists, and also making them pretty afraid. We think about what it might mean for preventing or treating DMD. We brainstorm some things we would need to know about CRISPR to know about its potential. We think about the level of explanation in our model that we should focus attention on. We decide we need to focus on what's happening to the DNA. We think that if it works, it could change the instructions so that people make the right kind of protein (dystrophin) and don't get DMD. But we remember that some people get it through a mutation, so we need to figure out when CRISPR can work. We also wonder how it is people are excited about something that works in a bacteria—how can cure a human disease? If you did fix the DNA, we wonder if we can use our model we made so far to predict what would happen if CRISPR works. We also wonder if this is a good thing—it could make people's lives better, but is it the right thing to do? We wonder if we can change ourselves with CRISPR, and if we can really make any organism we want. We decide we need to figure out how CRISPR works to begin with.</td>
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**Building toward**

NGSS PEs: HS-LS1-1 & HS-LS2-1

**Next Lesson:** Where we're going
In the next lessons, students explore one possible GET that holds promise for the future of accurate and efficient gene editing: CRISPR.
15 mins

Discuss within your Subject Area/Group how you might adopt some of these inquiry-based teaching tools to make your classroom student-centered.
Debrief:
How can you make incremental changes in your teaching?

Summary and Time for Questions
How can we start having an inquiry-based, student-centered classroom?

1. Start incorporating student discussions into your class activities.

2. Use strategies that encourage interaction among students (do a Google search for these):
   - Think-Pair-Share / Double Think-Pair-Share
   - Turn and Talk
   - Jigsaw Classroom
   - World Café Method

3. Develop and use guiding questions (prompts) to encourage student thinking and questioning.
What We Covered

1. Ways to improve science teaching and student learning
2. Inquiry-based learning and the student-centered classroom
3. Storyline approach to curriculum development
4. Example Genetics lesson that makes use of inquiry in a student-centered classroom
5. Using (student) discussions for active learning
6. Questions & Ideas for Future Work
Web Site and Contact Info

Access all workshop materials at: http://www.learningprogressions.com

Email: francis.molina@gmail.com
Thank you!