Designing NGSS aligned, PBL curriculum to support students’ understanding, engagement and socio-emotional learning

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What we will accomplish today

- CESE Project
- Framework for K-12 Science Education
- NGSS, 3D learning, PE
- Project based learning
- Optimal Learning Moments (OLM)
- Experience Sampling Method (ESM)
- Unit Development Process
- Assessment & Rubric Development Process
- Preliminary Results
PIRE Team (past and present)

• PI’s – Professor Barbara Schneider, Professor Joe Krajcik
• Research associates – Israel Touitou, Tom Bielik, Ryan Stowe, Chen I-Chien
• Education specialist – Deborah Peek-Brown, Kellie Finnie
• Graduate student- Chris Klager, Quinton Baker, Rachel Dezendorf, Sarah Maestrales
• Lead Teachers – Camron Cochran, Sandy Erwin, Steve Barry, William Carey, Julie Bennet
• Staff – Ellie Paulson
Crafting Engaging Science Environments (CESE)

- NSF funded, Multi-year project
- International Collaboration: US and Finland
- Large scale study - 130 teachers, 70 schools, ~8000 students
- Goal:
  “To increase student engagement and interest in the fields of science, technology, engineering, and mathematics (STEM)”
What is new in science education in the USA?

Knowledge in use

Learn about scientific ideas

Make sense of phenomena
A New Vision for Science Education

Scientific & Engineering Practices

Crosscutting Concepts

Disciplinary Core Ideas

Phenomena
Our Challenge

Build learning environments that:

• Foster deep and integrated understanding of important idea

• Engage students, i.e., create optimal learning environments, in learning science

• Support students in developing important scientific practices and 21st century competencies

• Support students to solve problems, think critically and innovatively
Optimal Learning Moments (OLM)

- Basing of the idea of “Flow”
- Intersection between skill, interest and challenge
- A temporal quality
- Situational dependent

(Csikszentmihalyi, 2008, Schneider et al, 2015)
Figure 1. A conceptual framework for optimal learning moments.

(Schneider et al, 2015)
Experience Sampling Method (ESM)

- Focus on the situational and contextual aspects of what happens in and out of the classroom
- Short, repeated surveys capture what students are doing and feeling *in-the-moment* (Csikszentmihalyi, 1975)
- Less opportunity for recall bias and socially desirable answers
- Students signaled in and out of science class
- Students signaled during the PIRE units and outside of it
Our Challenge

Build learning environments that:

• Foster deep and integrated understanding of important idea

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Our Solution:
Project-Based Learning (PBL)

• Meet important learning goals (NGSS performance expectations- PE)
• Pursue solution to *meaningful questions*
• Explore the question by participating in authentic, situated inquiry to “*figure out*” why phenomena occurs
• Engage in *collaborative activities* to find solutions
• Use learning tools and other *scaffolds* to help students participate in activities normally beyond their ability
• Create *artifacts* – tangible products – that address the driving question

Krajcik & Shin, 2014
Putting it all together

- How do we create units that aligned with the new vision for science education?
- How do we create three-dimensional assessment items?
- Do our units allow for the development of skills and knowledge alongside students engagement?
Our Claims

- Our design process allows us to create PE-aligned units and assessment tasks.
- Students learning these units show growth in their ability to answer three-dimensional assessment items.
- Students show an improvement in their engagement, OLM and other socio-emotional constructs.
<table>
<thead>
<tr>
<th>Unit Name</th>
<th>Driving Question</th>
<th>Phenomena</th>
<th>Performance Expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forces and Motion</td>
<td>“How can I design a vehicle to be safer for a passenger during a collision?”</td>
<td>car\cart collision</td>
<td>HS-PS2-1, HS-PS2-3</td>
</tr>
<tr>
<td>MagLev</td>
<td>“How do mag-lev trains function without touching the track?”</td>
<td>Magnetic Levitation</td>
<td>HS-PS3-5, HS-PS3-2</td>
</tr>
<tr>
<td>Electric Motor</td>
<td>“How can I make the most efficient electric motor?”</td>
<td>Toy motors</td>
<td>HS-PS3-1, HS-PS2-5, HS-PS3-3</td>
</tr>
<tr>
<td>Evaporation</td>
<td>“When I am sitting by the pool, why do I feel colder when I am wet than when I am dry?”</td>
<td>Evaporation of different liquid on the palm of your hand</td>
<td>HS-PS1-3, HS-PS3-2</td>
</tr>
<tr>
<td>Periodic Table</td>
<td>“Why is table salt safe to eat but the substances that forms it are explosive or toxic when separated?”</td>
<td>Reaction of Sodium with water</td>
<td>HS-PS1-1, HS-PS1-2</td>
</tr>
<tr>
<td>Conservation of Mass</td>
<td>“Can I make substances appear or disappear?”</td>
<td>Flash paper, invisible ink, Al/CuCl₂ reaction</td>
<td>HS-PS1-7</td>
</tr>
</tbody>
</table>
Our Design Process

- Research-backed
- Systematic
- Evidence-centered design
- Iterative
- Reproducible
- Generalizable
- Constitutes part of our validity argument

Krajcik & Shin, 2014
Before we proceed...
Sample Unit – Magnetic Levitation

**Identify Target PEs**

**HS-PS 3-5** Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

[Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.]

[Assessment Boundary: Assessment is limited to systems containing two objects.]

Students who demonstrate understanding can:

- Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.
Sample Unit – Magnetic Levitation

Unpack 3-dimensional components

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

**Science and Engineering Practices**

- **Developing and Using Models**
  - Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.
  - Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.

**Disciplinary Core Ideas**

- **PS3.C: Relationship Between Energy and Forces**
  - When two objects interacting through a field change relative position, the energy stored in the field is changed.

**Crosscutting Concepts**

- **Cause and Effect**
  - Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.

Identify Target PEs

- Unpack DCIs
- Unpack SEPs
- Unpack CCCs

Create Integrated Concept Maps

Articulate TLPs

Construct Evidence Statements

Develop Tasks & Scoring Rubrics

Unpack 3-dimensional components
Sample Unit – Magnetic Levitation

Create Integrated Concept Maps

Two Magnetic Objects

Interact Through a Magnetic Force Field

That Can Exert Magnetic Force

That is Dependent on The Shape of Joint Field

That Can Store Energy

Dependent on The Relative Position of the Objects

Unpack DCIs

Unpack SEPs

Unpack CCCs

Create Integrated Concept Maps

Articulate TLPs

Construct Evidence Statements

Develop Tasks & Scoring Rubrics

Identify Target PEs
Sample Unit – Magnetic Levitation

Articulate Task Learning Performances

• TLP 1- Students will develop a model to explain the motion of magnetic objects caused by the relationship between the direction of the magnetic force being exerted and changes in the shape of the magnetic field between the two objects.

• TLP 2- Students will analyze patterns in data to determine the relationship between the relative position of magnetic objects and the direction and magnitude of the magnetic force exerted by the field.

• TLP 3- Students will use patterns in data to explain the relationship between the relative position of magnetic objects and the energy stored in the magnetic field.
Sample Unit – Magnetic Levitation

Construct Evidence Statements

TLP 1- Students will develop a model to explain the motion of magnetic objects caused by the relationship between the direction of the magnetic force being exerted and changes in the shape of the magnetic field between the two objects.

Evidence statements: Students’ models will
• contain representations of the following components: direction of magnetic forces, changes in the shape of the magnetic field and the orientation of magnetic objects (like poles together and opposite poles together).
• show the relationship between these components and the motion of magnetic objects.
• show connections between changes in orientation of magnetic objects, changes in the magnetic field between the objects and changes in magnetic forces acting on the objects in the system.
Sample Unit – Magnetic Levitation

Develop Tasks & Scoring Rubrics

Tom found two bar magnets stuck to the fridge. He held the magnets close to one another, let one of them go and observed what happened. He then did that again, only this time flipping one of the magnets. In the first try, the magnets were repelled and in the other, they were attracted (pictures A and B).

1. draw a model to explain why in the first observation the magnet bars moved further apart while in the second observation they got closer together.
Sample Unit – Magnetic Levitation

Develop Tasks & Scoring Rubrics

<table>
<thead>
<tr>
<th>FKSA</th>
<th>Proficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ability to construct a model of the magnetic field lines and the forces acting in the system to explain the observation.</td>
<td>Proficient (3)</td>
</tr>
</tbody>
</table>

- **Proficient (3)**: Student construct a correct model for the magnetic field lines for both orientations as well as a correct representation of the directional forces acting in the system.
- **Developing (2)**: Student construct a correct model without adding a representation for the forces OR construct a correct model with an incorrect representation of the forces OR construct an incorrect model for the field lines with a correct representation of the forces.
- **Beginning (1)**: Student construct an incorrect model of the field lines and the forces acting in the system.
Task Validation

Create Assessment Task

Content Validation

Cognitive Interviews

Revised Tasks

Student Responses

Statistically Valid Scales
Sample Unit – Magnetic Levitation
Case Study Results

- Single class
- ~30 students
- Large Suburban Area
- 24% of free/reduced lunch
- Mostly African-American (96%)
- Below state average in science
Sample Unit – Magnetic Levitation

Students Responses

Pre-Test

Post-Test
Sample Unit – Magnetic Levitation
Initial Results

<table>
<thead>
<tr>
<th>Construct</th>
<th>Odds Ratio</th>
<th>SE</th>
<th>Z</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>OLM</td>
<td>2.1454</td>
<td>0.6844</td>
<td>2.39</td>
<td>0.017</td>
</tr>
<tr>
<td>Imagination</td>
<td>1.4399</td>
<td>0.3123</td>
<td>1.68</td>
<td>0.093</td>
</tr>
<tr>
<td>Solving Problems with Multiple Solutions</td>
<td>1.6861</td>
<td>0.3620</td>
<td>2.43</td>
<td>0.015</td>
</tr>
</tbody>
</table>
Sample Unit – Forces and Motion
Case Study Results

- Single class
- ~25 students
- Large Suburban Area
- Mostly caucasian
- Below state average in science scores
My Claims

- Our design process allows us to create PE-aligned units and assessment tasks.
- Students learning these units show growth in their ability to answer three-dimensional assessment items.
- Students show an improvement in their engagement, OLM and other socio-emotional constructs.
The future...

- A lot of data - at the student/teacher level
- Learning and engagement
- Gender, Ethnicity, SES
- English Language learners
- Machine learning
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Thank you!

"You're telling me it will take 13 years to install my education! What kind of outdated software is this school using?"