Design Principles and Theoretical Foundation of Project-Based Learning

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Our Goals

• Improve the learning of science for all students
• Reduce the achievement gap among various populations of students
• Increase the number and diversity of students completing advanced science and technology degrees
• Increase the number and diversity of students in the science and technology careers
• Improve students’ decision and solving problems
  • Using evidence and reasoning
• Improve in students innovating and learning more.
In school, most students, particularly students from underrepresented backgrounds, are not:

- Developing useable knowledge to solve problems, make decisions, and learning more
- Motivated to pursue STEM as a career
- Empowered to explain the world
Build learning environments that allow all students to:

• Foster integrated and useable knowledge of science
• Develop motivation to learn science
• Develop scientific practices and 21st century competencies
• Solve problems, make decisions & think innovatively
How can we change classrooms to promote optimal learning environments?

or

or
Learn Science by Doing Science
Our Solution: Project-Based Learning

• Pursue solutions to a *driving question*
• Focus on key learning goals
• Explore the driving question by participating in authentic, situated inquiry
• Engage in collaborative activities to find solutions
• Use learning technologies and scaffolds to help students participate in activities normally beyond their ability
• Create artifacts – tangible products – that address the driving question
• Focus on all learners
Model to support student learning

Question: How do you support all students – particularly diverse students, English Language Learners, and at risk students – in learning science to make sense of phenomena, solve problems and innovate?

**Theoretical foundation:** Expert knowledge organization, situated cognition, prior knowledge, active construction, universal design, social interaction, cognitive tool

**Intervention:** Project-based Learning, Professional learning community, Family and community

**Engaging classroom environments:** explore phenomena, sense making

**Enhanced Student learning:** useable knowledge, agency to learn and build knowledge, motivation to learn more, improved achievement
Theoretical Considerations

1. Expert knowledge organization
   - Structured around big ideas and practices of the discipline

2. Situated cognition
   - Meaningful and real world context linked to the ideas

3. Prior knowledge and experiences
   - Families, home, community

4. Active construction
   - Use multiple representations, apply information, experience and make sense of phenomena
Theoretical Considerations

5. Principle of Universal Design
   – Multiple means of expression
   – Multiple means of engagement
   – Multiple representations

6. Social Interactions and language development
   – Collaborative interactions with peers and more knowledgeable others
   – Content specific discourse

7. Cognitive tools
   – Scaffolds
   – Computing/communication technologies
Model to support student learning

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Project-based Learning Intervention

1. Focused on meeting performance learning goals
   – Performance orientated
2. Contextualized in meaningful environments
   – Use of driving question and anchoring phenomena tied to student lives
3. Focused on making sense of phenomena
   – Ask/Refine Questions, Design, Making models, constructing explanations
4. Develop artifacts
   – Represent Student Emerging Knowledge
5. Engage in collaboration
   – Learning Communities - Listen, Share, Take Risks, Debate
6. Use Learning Technologies
   – Artifact Development, Collaboration, Information Access
Professional Learning Community
• Experience essential aspects of intervention (explore a DQ)
• Educative Curriculum
• Online professional communities

Community and family Connections
• Links to family background
• Community resources
Learning Goals Expressed as Performances

Focus on useable knowledge

- Understand a few powerful ideas and practices
- Allow learners to develop understanding that can be used to solve problems and explain phenomena
- Provides explanatory power
- Serve as thinking tools
Why build towards a learning goals?

Establish Coherence

• Lessons fit together coherently
  – Science ideas build upon each other so that they become more sophisticated over time
  – Lessons link together

• Different scientific practices are used together with big ideas from disciplines to explain phenomena.
Driving Questions & Phenomena

- Driving questions
  - Drive and organize instruction
  - Anchored in the lives of learners
  - Deal with important, real-world questions

- Anchoring Phenomena
  - Experience Phenomena in Context
    - River Walk
    - Bird Walk
  - Case Studies
    - Video
    - Text based
Why Driving Questions?

- Students need to see the importance of what they are learning.
- What students learn needs to be connected to students’ world and the doing.
- Implications for students beyond the realm of school.
- Students develop a need to know.
<table>
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<tr>
<th>Physics Driving Question</th>
<th>Learning Goal(s)</th>
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| How can I design a vehicle to be safer for a passenger during a collision? | • Analyze data to support the claim that Newton’s second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.  
• Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision. |
<p>| How do mag-lev trains function without touching the track? | • 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. |</p>
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<tr>
<th>Chemistry Driving Question</th>
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| When I am sitting by the pool, why do I feel colder when I am wet than when I am dry?  | • Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.  
• Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles |
| Why is table salt safe to eat but the substances that forms it are explosive or toxic when separated? | • Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms  
• Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. |
Pursue solution to a meaningful question

How can I design a vehicle to be safer for a passenger during a collision?

Engaging in Investigation – learning science by doing science!

- Messing about: exploring, making initial observations, manipulating objects, experiencing phenomena. What do you see?
- Obtaining Information: asking others, purposeful reading, evaluating information. What is known about your question?
- Asking and refining question: Wondering, making predictions, asking what if? What would happen if......
- Constructing and evaluating models: Draw pictures to illustrate ideas. Revise based on new evidence. Does my model explain all the data?
- Planning and designing how you will answer your question: Constructing the investigation plan. What variables will you explore? Will the design allow me to answer the question?
- Sharing your ideas: Presenting your ideas, receiving feedback, listening to others. How can I improve my work from what others say?
- Using argumentation to support your position: Provide evidence and reason to support your ideas, debate ideas, question the validity of claims. Have I presented enough evidence to support my case?
- Constructing explanation using evidence and scientific principles? Do I have the appropriate data? Do I have enough data? Have justified way the data counts as evidence?
- Analyzing and interpreting data: Make sense of the data, analyze and transform the data. What patterns do I see?
- Conducting the experimental work: Assembling the apparatus, gathering the data. Am I follow my plan?
Elements of doing science

• Asking and refining questions: Wondering, Making predictions, asking what it? What would happen if...?

• Planning and carrying out the experimental work: Deciding on the variables, deciding on plan, assembling the apparatus, gathering the data. Am I follow my plan?

• Analyzing and interpreting data: Make sense of the data, analyze and transform the data. What patterns do I see?

• Constructing and evaluating models: Draw pictures to illustrate ideas. Revise based on new evidence. Does my model explain all the data?

• Constructing explanation using evidence and scientific principles? Do I have the appropriate data? Do I have enough data? Have I justified way the data counts as evidence?

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Why engage in scientific practices?

• Students
  • Use knowledge to figure out problems
  • Apply ideas
  • Synthesis ideas
  • Make plans
  • Need to be innovative
  • Build explanatory ideas
Engaging in Collaborative Activities

- **Students**
  - Use language to express knowledge
  - Express, debate and come to resolutions regarding ideas
  - Debate the viability of evidence
  - Work together to make meaning
  - Build explanations

- **Students learn from knowledgeable others**
  - Instructors
  - Members of the Community
Artifact Construction

- Artifact construction provides opportunities for students to
  - Represent their emerging understanding
  - Develop relationships and connections between ideas
  - Construct, express, and revise their understanding
  - Use innovative ideas
  - Make thinking sharable and visible
  - Engage in the design process

- Instructor feedback and student revision is a central aspect

How can I make a better toy?
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Improvement in classroom environments

Increase and enhanced

• opportunities for students to explore and explain science phenomena and solve problems
• science talk, writing and reading in the classroom
• use of science ideas and science and engineering practices
• use of science ideas and language in exploring and explaining science and solving problems
• Opportunities to work together on challenging ideas
Student learning

- Increased use of science ideas in speaking, writing and talking science
- Improved ability to
  - Develop evidence-based explanation (make claims, use evidence and provide reasoning.
  - Construct models that provide a causal account of phenomena
  - Talk, write and speak science
- Increased interest in exploring science
Student learning

- Increased performance on measures of 3-dimensional learning to make sense of phenomena and solve problems

- Enhanced efficacy and metacognition in science learning and in language usage

- Increased motivation and engagement to explore science using scientific practices, language and mathematics
Use of design-based research

Design, development and testing of innovations to improve teaching and learning about persistent educational problems

A commitment to improve practice and to contribute to the literature

A commitment to iterative, collaborative design

Cycles of formative research to inform and improve the innovation and to inform the literature

Teaching experiments, pilot, field, and efficacy studies
Elements of Figuring Out in PBL

**Phenomena**
What was the event(s) in the world that happened that we need to explain?

**Question**
What about the phenomena do we need to explain?

**Science and Engineering Practices**
How are we modeling, explaining, etc. the phenomena, or designing a solution to solve the problem?

**New Ideas**
What did we figure out using these practices?
What pieces of the scientific ideas did we figure out?
What new ideas do we have?
What evidence do we have?

Growing evidence for PBL leading to more learning
3. B. Schneider and colleagues – Optimal Learning Environments (2015)
6. R. Schneider, Solloway and colleagues -- (2001)
A concluding message

• PBL classrooms become learning environments where teachers and all students engage in science to design and carry-out investigations to make and debate claims supported by evidence and reasoning

• Such environments foster imagination, problem solving, engagement, communication capabilities, working together, useable knowledge, and agency for all students
Thank You!

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