How People Learn 101: Theory and Practice

Sean Brophy

Network for Computational Nanotechnology (NCN)

Electrical and Computer Engineering

School of Engineering Education

sbrophy@purdue.edu

PURDUE UNIVERSITY

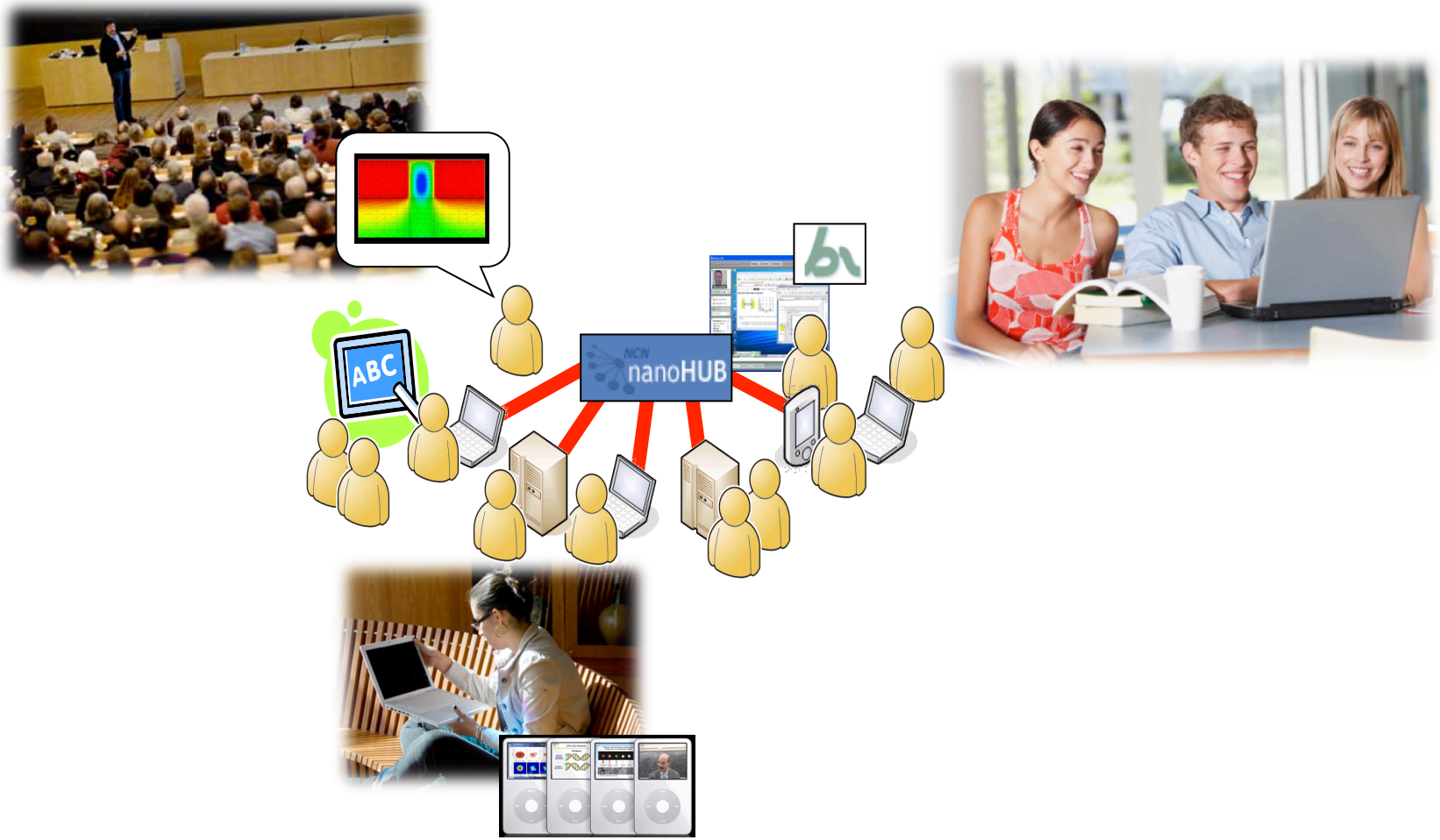
Presented at the

NCN Workshop on Simulation-based Learning

November 5-6, 2009

Big 10 Conference Center

Blending experiences with HUB Technology



Providing a framework for Designing Instruction

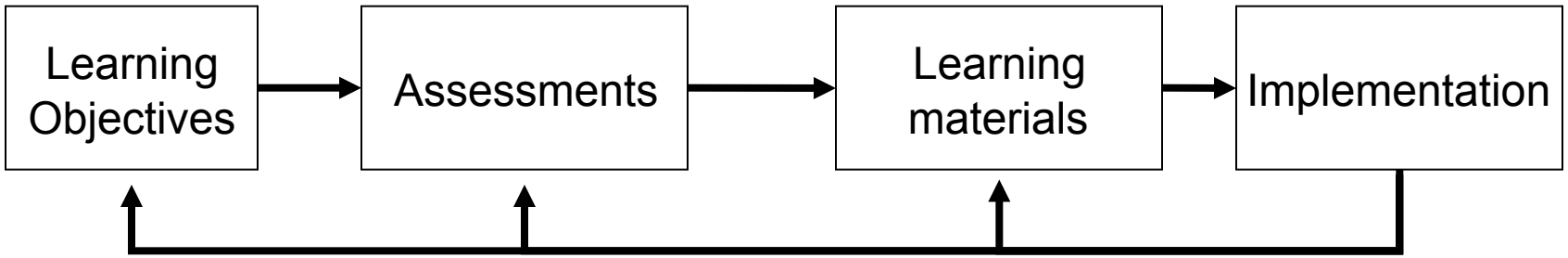
- Driving questions for this session
  - »What makes an effective learning environment?
  - » What factors influence student learning?
  - » What opportunities exist for my students?

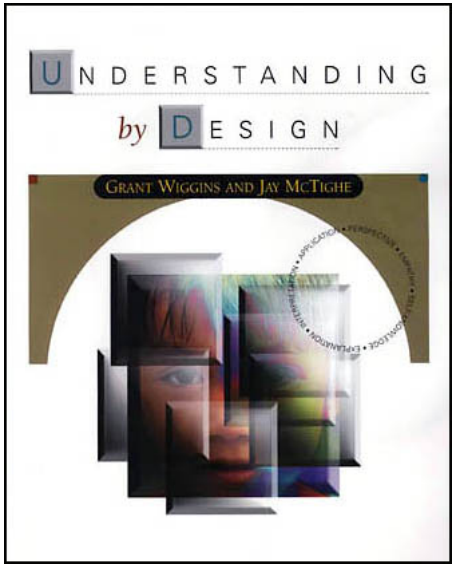
Instructional Design Process

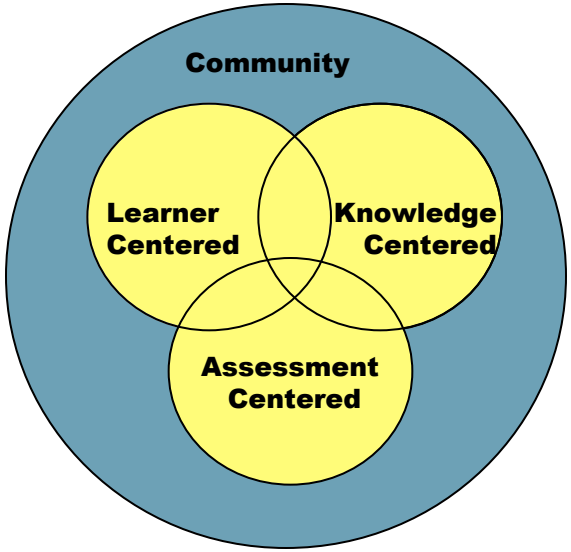
What are students going to learn?

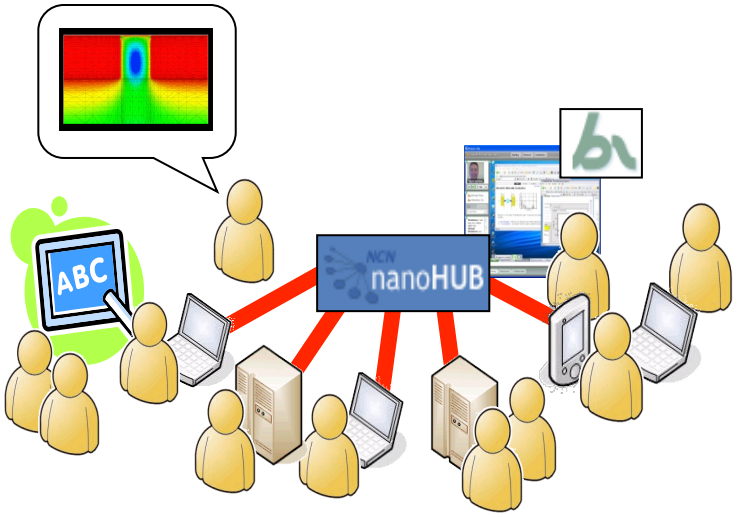
What evidence will indicate students learned it?

How will students learn it?







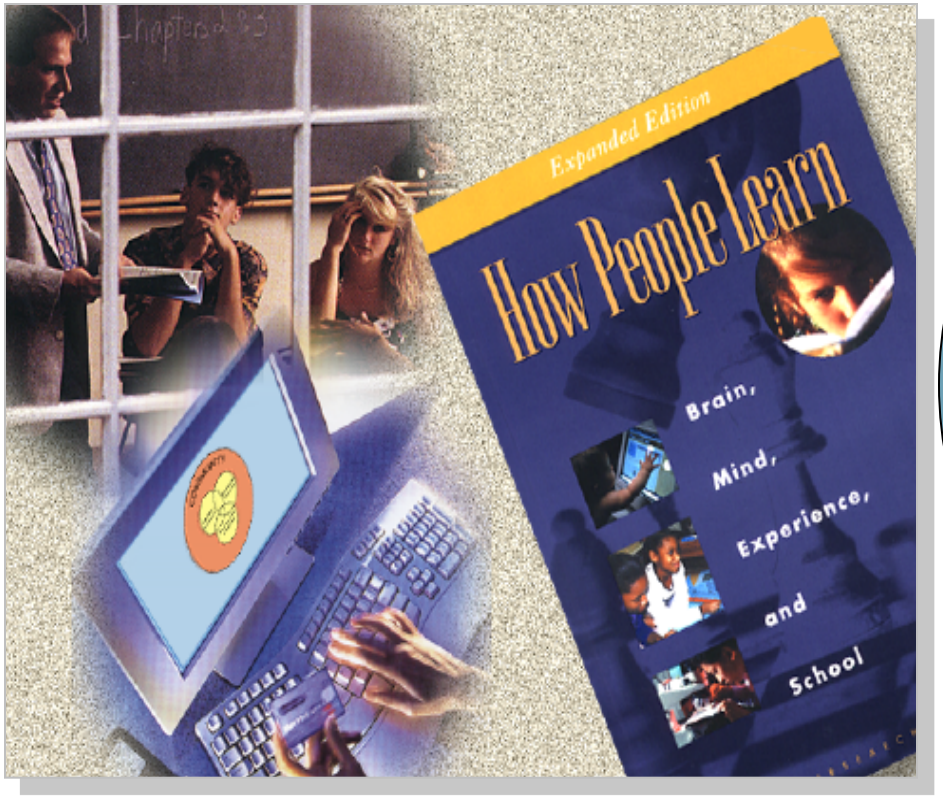


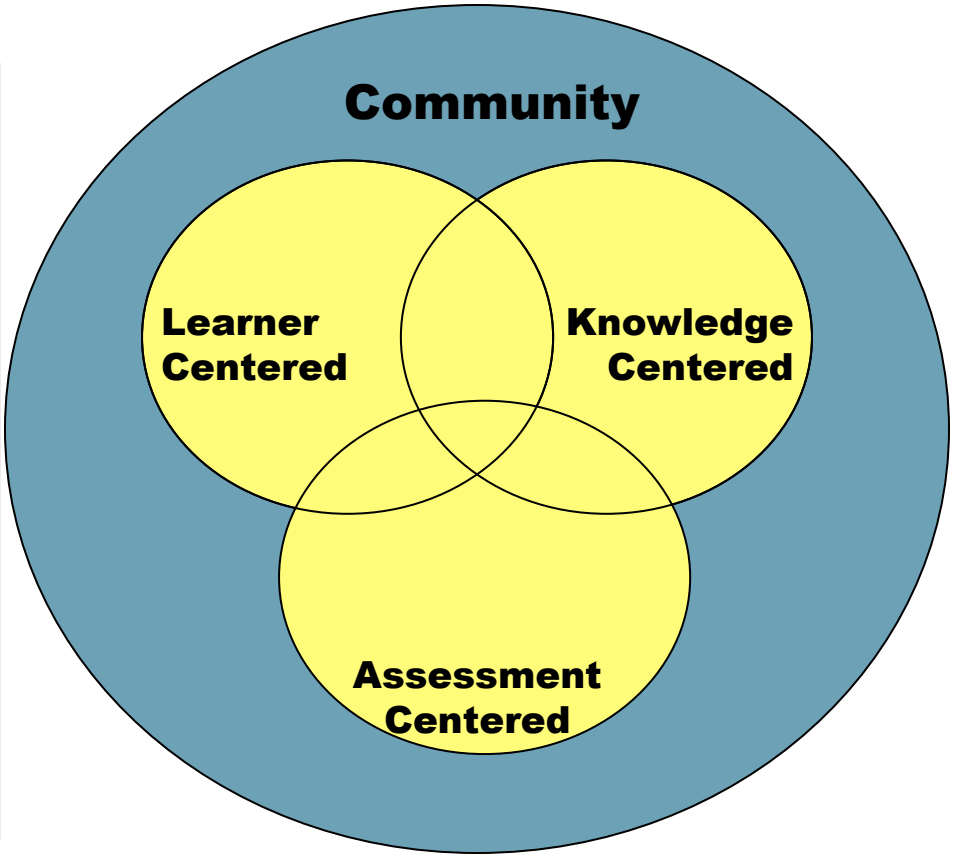
Possible Learning Objectives with Simulations and Models

- How do computational scientists and engineers use simulations and models to support their inquiry?
- Using simulations to support inquiry
  - » **Design** experiments to answer driving questions
  - » Generate data to **explain** behavior of a phenomenon
  - » **Compare and contrast** system states to **explain** governing principles
  - » **Analyze** design decision of a nanoscale device
- Building computational models to support inquiry
  - » **Apply** computational/numerical techniques
  - » **Validate** models relative to empirical data
  - » **Identify** and explain limits of a particular model
  - » **Adapt** models to increase accuracy and precision

Source: Magana , A. D.(2009)

How People Learn: Brain, Mind, Experiences and School

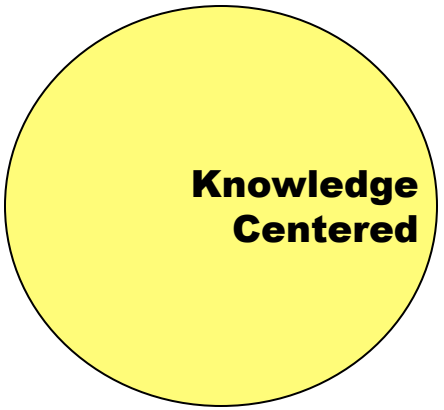




Often referenced in NSF RFPs

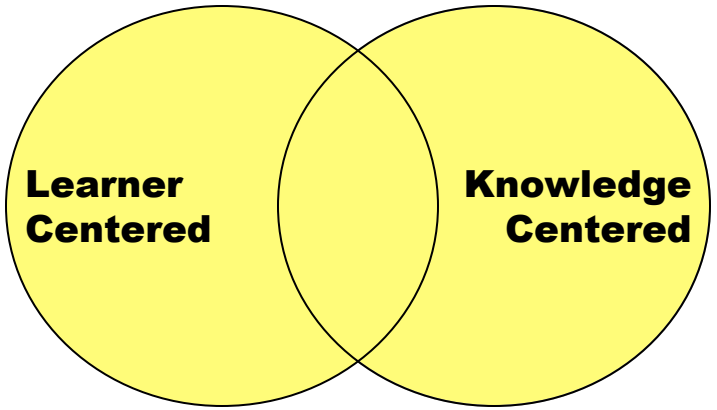
http://www.nap.edu/openbook.php?record_id=6160

Defining Necessary Knowledge



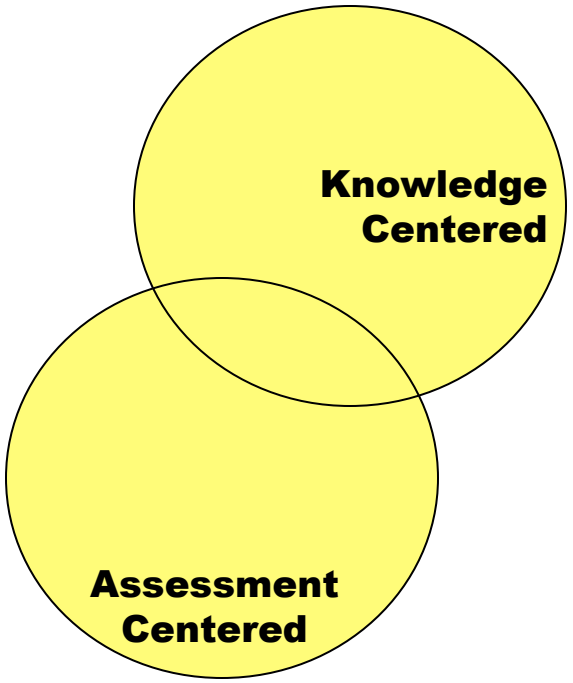
- Targeted goals for learning
  - »Fundamentals
    - ✓ Principle concepts
    - ✓ Skills and facts
  - »Important concepts
  - »Familiarization with related concepts
- Organized to facilitate acquisition and application

Identifying Learners Needs



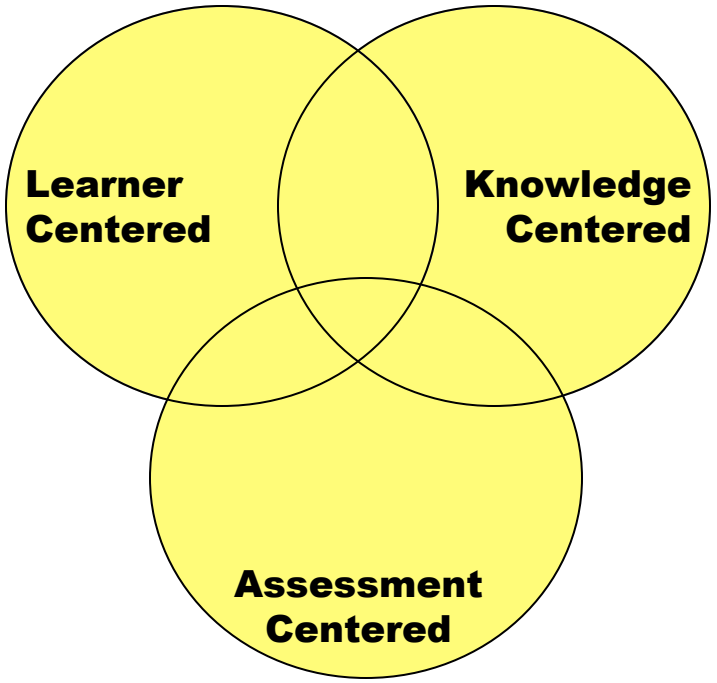
- Learner Centered
  - Lack of prior knowledge
    - Domain concepts
    - Conditions of applicability
  - Preconceptions
  - Hard to comprehend concepts
  - Developing mastery (e.g. mathematics)
  - Developing identity

Assessing Knowledge



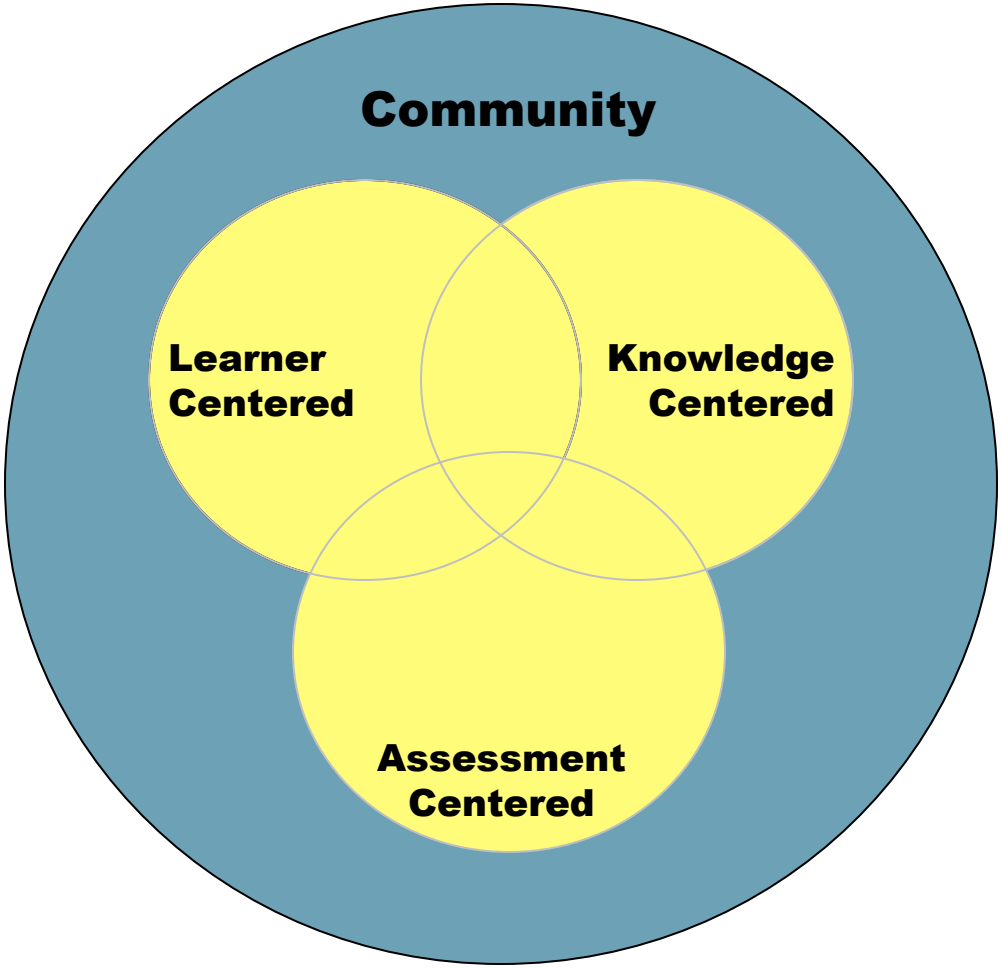
- Summative Assessments
  - End of Unit
  - Test of Mastery
  - Sequestered problems solving

Assessment Centered: Track Development



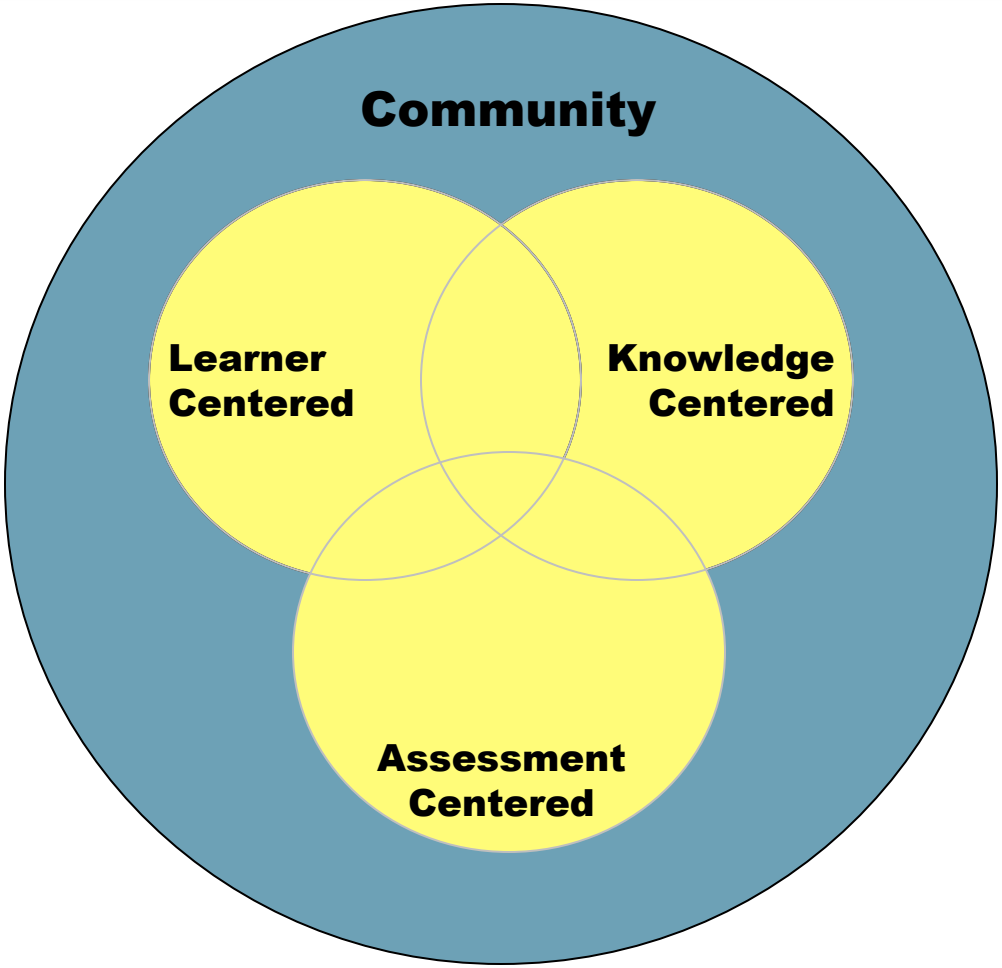
- Formative Assessment
  - Continuous opportunities to demonstrate what students know
  - Student reflection
  - Develop metacognitive skills
  - Facilitates continuous improvement of instruction
    - e.g. Personal Response System

Community Centered



- Connections with instructor, peers and professional community
  - »Classroom + department
  - »Understanding perspectives – e.g.
    - ✓ Approach to problems
    - ✓ Prioritizing design factors
  - »Developing identity
    - ✓ Student
    - ✓ Professional

How People Learn (HPL) Framework



HPL Framework provides guidelines for identifying critical factors associated with effective *learning environments*.

Professors' instructional approach

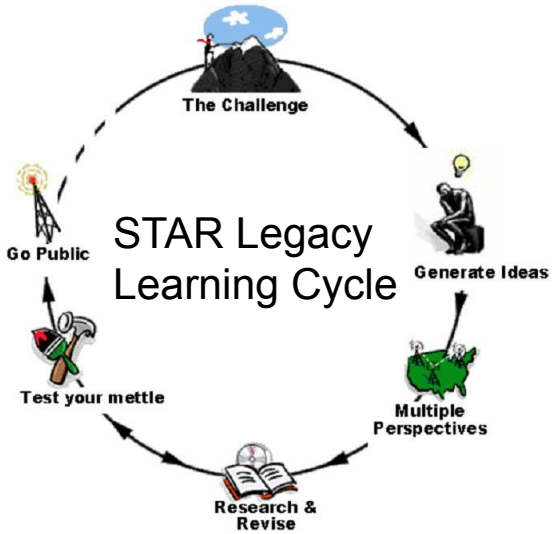
Example of an inquiry based instructional model:

Challenge – presents a complex problem that requires synthesis of concept associated with critical concepts to be taught

Generate ideas – ask students to articulate what they know and generate questions about what they need to learn

Multiple perspectives – provides experts' ideas about the challenge that students compare with their ideas.

Research and Revise – provide rich resources and learning activities around critical concepts of the challenge



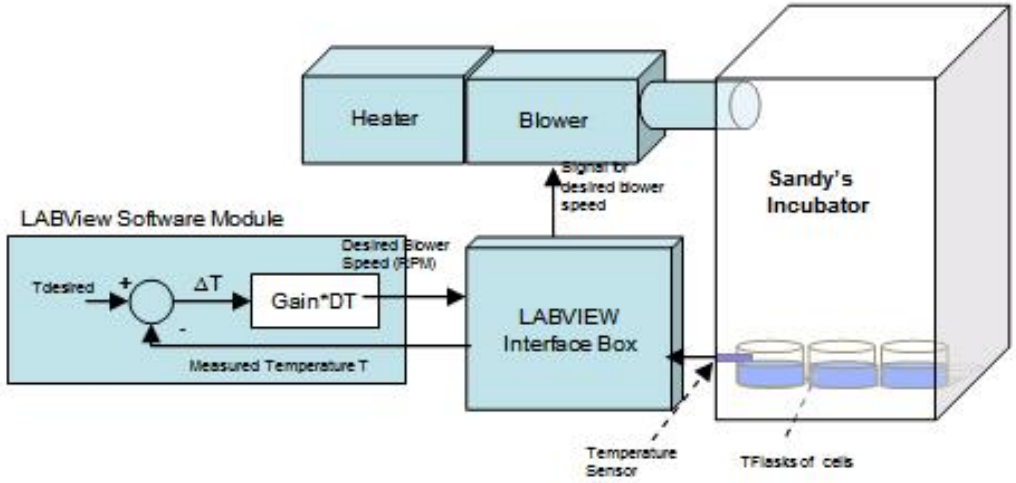
Test your mettle – are formative assessment activities that help learners test and refine their thinking of critical concepts

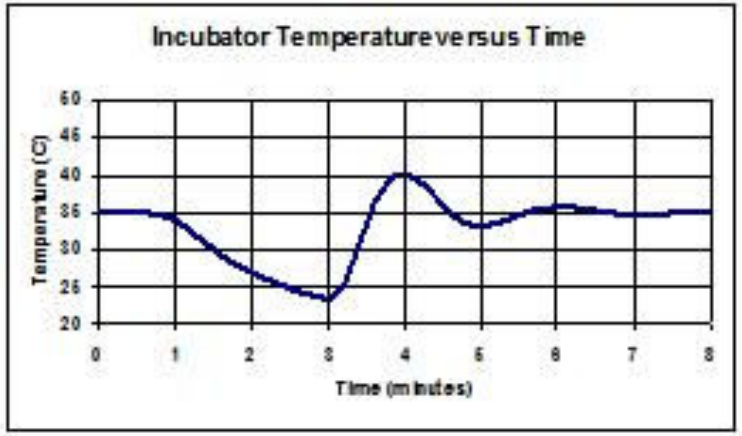
Go Public – is a final assessment requiring the synthesis of concepts to solve the original challenge or similar challenge

Example 1- First year engineering

- First Year Engineering Course – Engineering Problem Solving and Computational Tools
  - N= 420 students
- Objectives
  - Apply MATLAB numerical analysis to a mathematical model
- On-going objectives
  - Represent complex system with a graphical model to achieve a specific goal (troubleshoot)
  - Define the functional model of a dynamic system

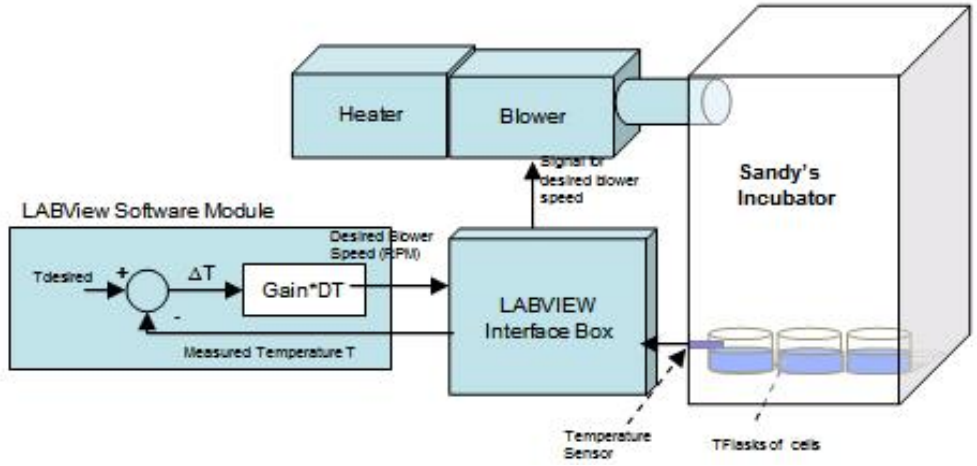
Preparation for class - online

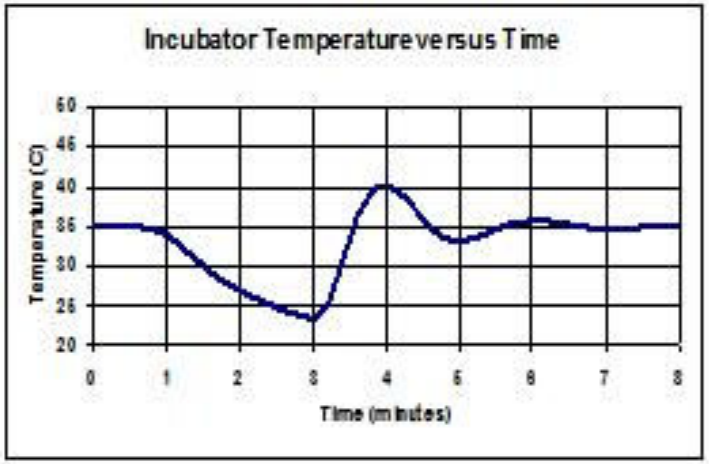




A bioengineering graduate student built a simple incubator to support her cell growth experiment. Her experiment requires repeatedly opening the door to sample the cells. When the door is closed the performance of the system was less than optimal as shown by the overshoot in temperature at 4 seconds.

Preparation for class - online module



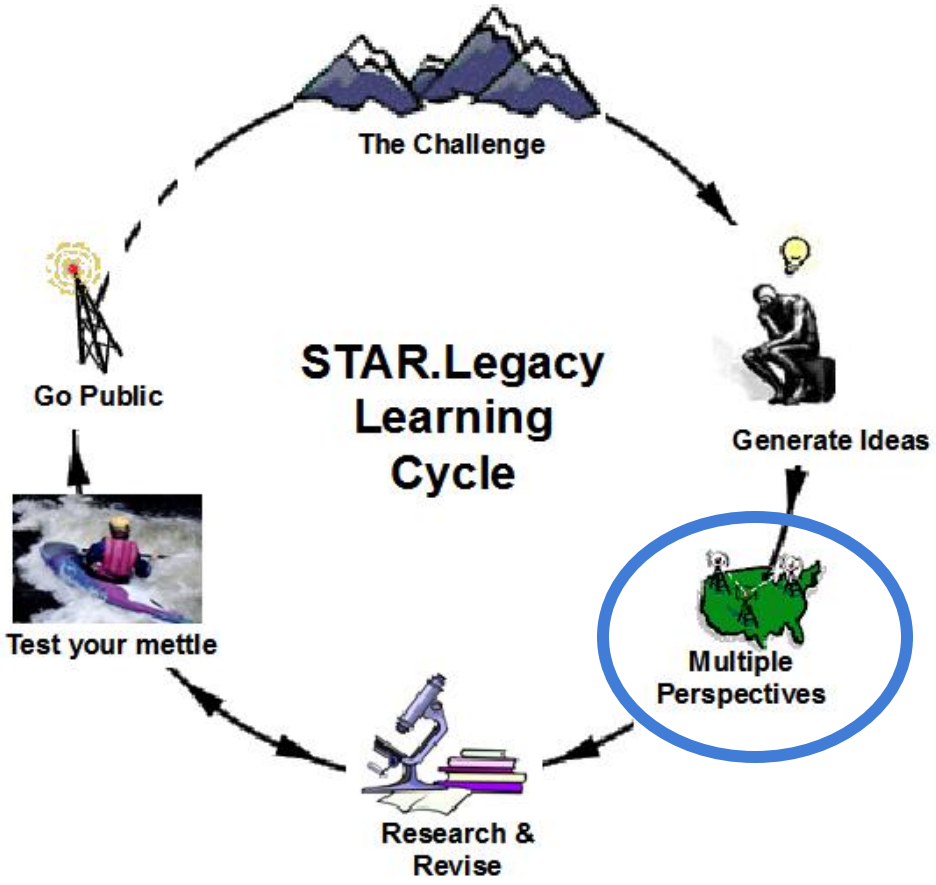


What questions do you need to investigate in order to better help Sandy?

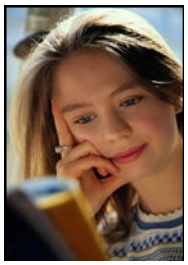
What ideas do you have for Sandy on how she can improve the performance of her system?

What do you think first year engineering students would notice in this problem as they answer these questions?

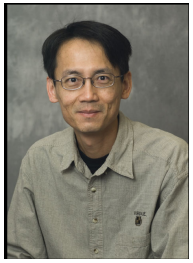
Challenge Based Instruction



Multiple Perspectives



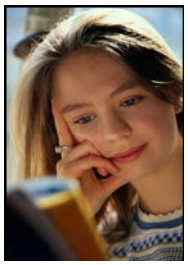
***Jennifer Wilson*, Junior in Mechanical Engineering**
My first thought to prevent overheating is to set up the blower to turn-off before the temperature reaches a desired temperature. However, I think the temperature would simply peek near the desired temperature and then cool down to the turn-off temperature. Then the heater would cycle on and off keeping the temperature at the lower turn-off temperature.



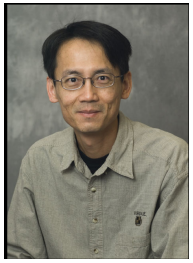
***Joe J. J. Lin*, Engineering Education, B.S.I.E., M.S.I.E.** Click for bio
"Currently the slope of temperature between time= 3 to 4 minutes is very steep. However, if we control the blower right, the slope should become less and less steep when the temperature approaches 35 C. So the problem is either the controller's adjustment is not frequent enough, or the blower was not controlled properly. "This makes me think... "Was the blower speed adjusted frequently enough? Did we use the proper 'Gain' value to adjust the blower speed?"

***Dr. K. Newburg, PhD.*, Biomedical Engineering**
I think Sandy has put together a great test apparatus. I'm pleased she was able to make use of our extra parts. To improve her set up she might want to construct a simple mathematical model of the system and then run an analysis to determine the best Gain for the controller. She could run a quick test to determine how fast the system heats up to the maximum temperature and how long it takes to cool off with the door closed. With this data I think she could make a mathematical model.

Multiple Perspectives



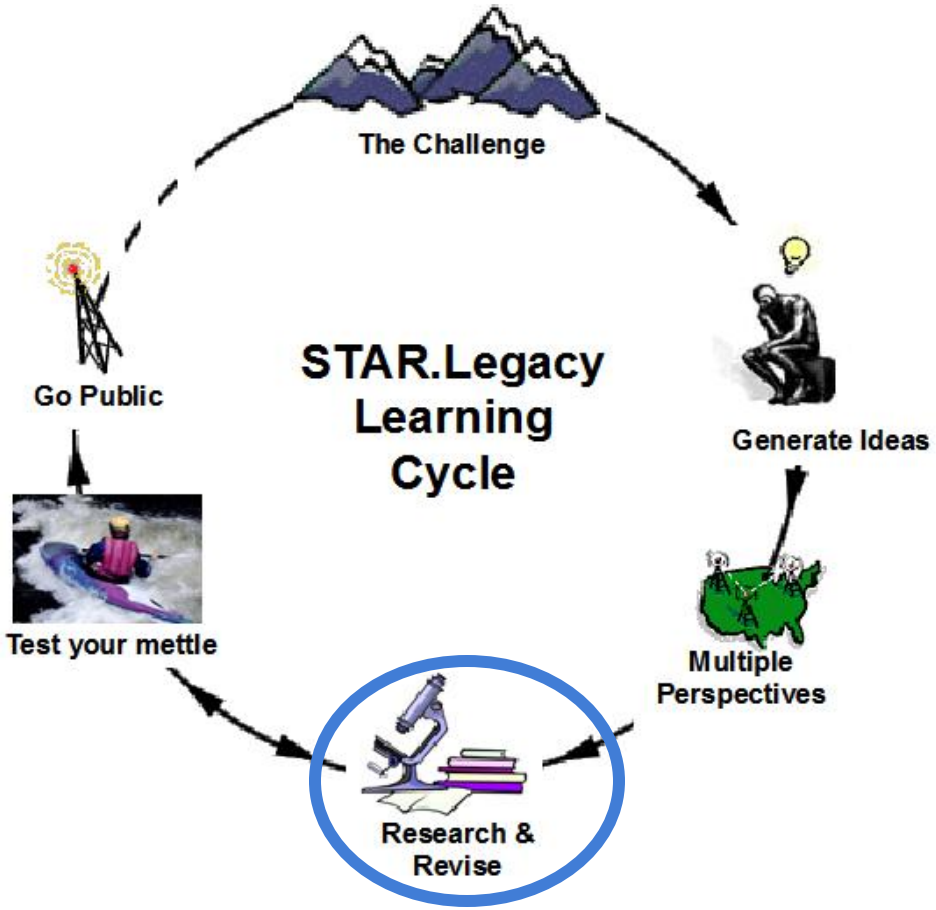
***Jennifer Wilson*, Junior in Mechanical Engineering**
My first thought to prevent overheating is to set up the blower to turn-off before the temperature reaches a desired temperature. However, I think the temperature would simply peek near the desired temperature and then cool down to the turn-off temperature. Then the heater would cycle on and off keeping the temperature at the lower turn-off temperature.



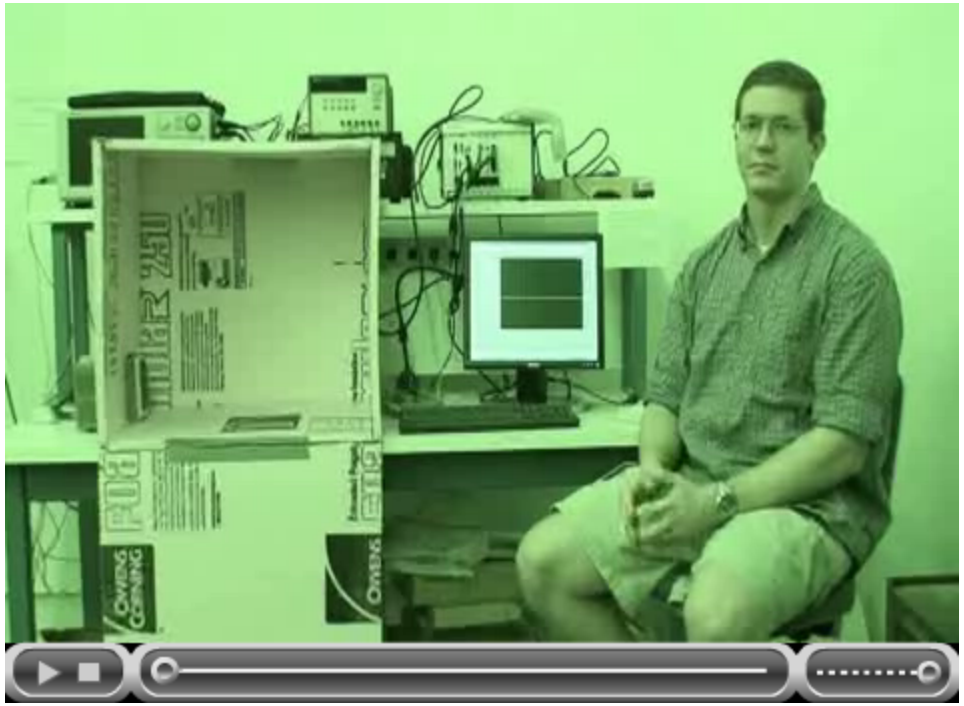
***Joe J. J. Lin*, Engineering Education, B.S.I.E., M.S.I.E.** Click for bio
"Currently the slope of temperature between time= 3 to 4 minutes is very steep. However, if we control the blower right, the slope should become less and less steep when the temperature approaches 35 C. So the problem is either the controller's adjustment is not frequent enough, or the blower was not controlled properly. "This makes me think... "Was the blower speed adjusted frequently enough? Did we use the proper 'Gain' value to adjust the blower speed?"

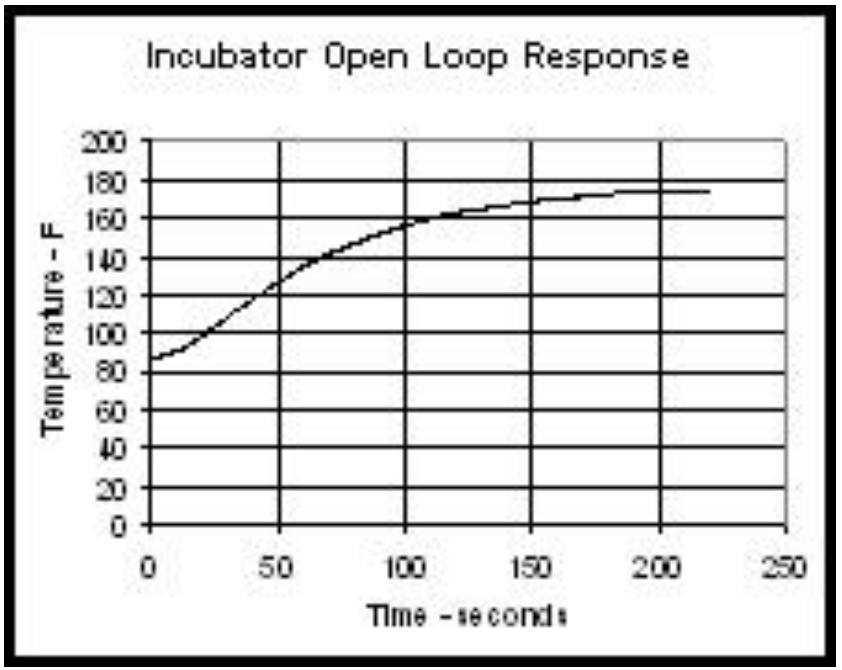
***Dr. K. Newburg, PhD.*, Biomedical Engineering**
I think Sandy has put together a great test apparatus. I'm pleased she was able to make use of our extra parts. **To improve her set up she might want to construct a simple mathematical model of the system and then run an analysis to determine the best Gain for the controller.** She could run a quick test to determine how fast the system heats up to the maximum temperature and how long it takes to cool off with the door closed. With this data I think she could make a mathematical model.

Challenge Based Instruction



Modeling the system - Open Loop Response Test





At what point on this graph would you estimate that the rising temperature versus time is no longer linear?

Focus: Blended Learning

Before Class

- Pre-Tests
- Preparatory resources
- Adaptive exercises

In Class

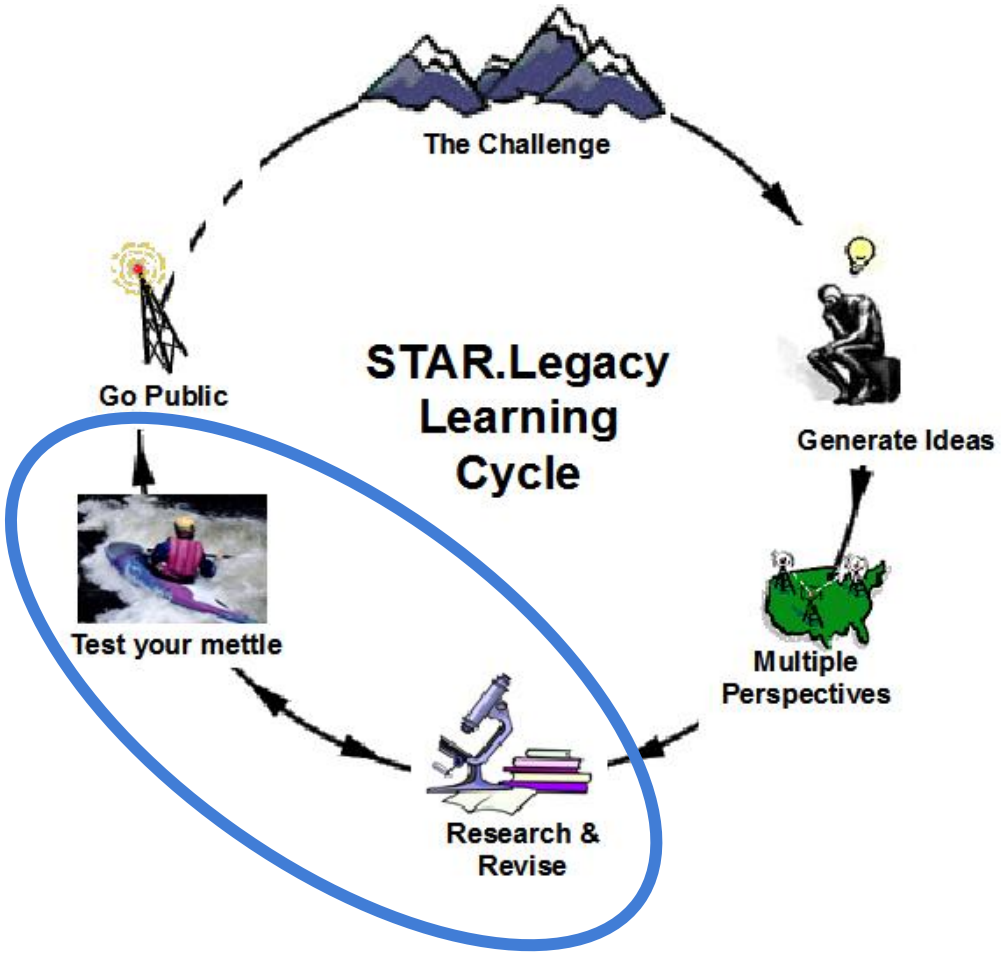
- Discussions/lecture
- Traditional sensing (Q&A, quizzes)
- Feedback systems (PRS, CPS)

After Class

- Adaptive exercises
- Remedial resources
- Post-Tests

Integrating all aspects of the learning environment

Challenge Based Instruction



Methods

- Instructional sequence
  - » Assign module as part of homework a week before lecture
  - » Review generate ideas and questions asks
  - » Blend these ideas into the lecture/discussion
- Study 1 – Incubator control system
  - » Fall 2007 – 967 students completed the module
  - » Coded Generated Ideas
  - » Coding Questions Generated

Possible Learning Objectives with Simulations and Models

- How do computational scientists and engineers use simulations and models to support their inquiry?
- Using simulations to support inquiry
  - » **Design** experiments to answer driving questions
  - » Generate data to **explain** behavior of a phenomenon
  - » **Compare and contrast** system states to **explain** governing principles
  - » **Analyze** design decision of a nanoscale device
- Building computational models to support inquiry
  - » **Apply** computational/numerical techniques
  - » **Validate** models relative to empirical data
  - » **Identify** and explain limits of a particular model
  - » **Adapt** models to increase accuracy and precision

Source: Magana , A. D.(2009)

References

- How people learn – Bransford, Brown and Cocking
  - » http://www.nap.edu/openbook.php?record_id=6160
- Understanding by Design – Wiggins and McTighe
  - » Google Books reference
    - ✓ http://books.google.com/books?id=N2EfKlyUN4QC&dq=understanding+by+design&printsec=frontcover&source=bn&hl=en&ei=yOu5S9TiKIGdlgfCmsGVCg&sa=X&oi=book_result&ct=result&resnum=4&ved=0CBkQ6AEwAw#v=onepage&q=&f=false

http://www.nap.edu/openbook.php?record_id=6160