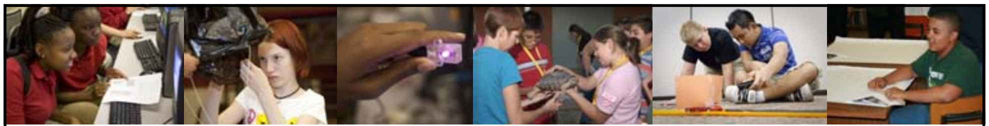
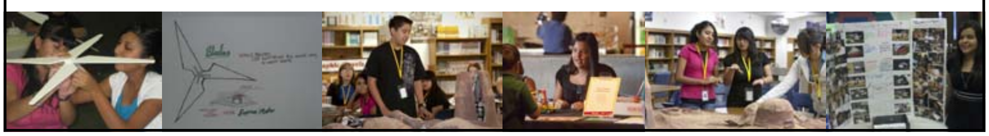


Design-based Research: A Framework for Designing and Sustaining Novel Teaching and Learning Experiences in K-12 Engineering Education

Beverly Parsons
Tirupalavanam G. Ganesh



Design-based Research

- Sullivan (2006) and National Research Council (2009) — the educational challenge is an **engineering design challenge**
- **Design-based research** — methodology for understanding how, when, and why educational innovations work in practice
- Research in K-12 engineering education is an **iterative process** akin to that in the design-based research efforts in education (Barab & Squire, 2004; Design-Based Research Collective, 2003; Kelly, Lesh, & Baek, 2008)

Barab, S., & Squire, K. (eds) (2004). Design-based research: Clarifying the terms. *Journal of the Learning Sciences,* 13 (1). Design-based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher,* 32(1), 5-8.
Kelly, A. E., Lesh, R. A., Baek, J. H. (2008). *Handbook of design research methods in education: Innovations in Science, Technology, Engineering and Mathematics learning*

2

Learning through **E**ngineering design **a**nd **P**ractice (LEAP)

- Design-based research — Exploring possibilities for **novel learning and teaching environments**
- Views the **design** of the engineering **education experience** and its **specific enactment**s as objects of research
- Grounded in **needs, constraints, and interactions** of local contexts
- Leads to eventual development of robust explanations of practice in context
- Provides principles that can be localized for others to apply
- Lays groundwork for education innovation

3

Learning through **E**ngineering design **a**nd **P**ractice (LEAP)

Project Funding and Sites

- NSF ITEST Project funded September 2007, $1.08 million
- Collaborative effort with multiple disciplinary experts
- Four middle-school sites; after-school program offered for two cohorts; cohorts experience the program beginning in their 7th grade
  - Cohort 1 (2007-09): Carson and Powell Jr High Schools
  - Cohort 2 (2008-10): Mesa and Smith Jr High Schools
- Field-testing in Mesa Arts Academy--Charter School as an in-school program and the Boys and Girls Club of Mesa - as an after-school program (2010-11)

4

LEAP: Project Philosophy

Project Philosophy

- The idea of **low floors** (easy for novices to get started) and **wide walls** (possible for learners to gain expertise and work on increasingly sophisticated projects)
- Ensure that learners are **free to explore materials and resource***s* of their own interest
- Ensure that there is **no single correct solution to the challenge**; instead there could be many possible solutions
- Ensure that there is **no mystery about assessment**
- **Place** the **technological tools** used in the learning experiences **in the hands of students**: to take home, keep, explore at leisure

5

LEAP: Influences that shaped Project Design Principles

Project Design Principles

- *Learner centered Instruction:* Problem-based Learning / Project-based Approach
- *Instructional Planning:* The Learning Cycle-5E Model (Engage, Explore, Explain, Evaluate, Elaborate)
- *Learning in Context:* Cognitive Apprenticeship
- *Tools:* Construction Kits (e.g., PICO Cricket Kits, Lego Mindstorms NXT, Electrical Circuit kits, Graphing Calculator Robots, Vernier Probeware, Hydrogen fuel cell kits) and found objects
- *Other Tools:* Vocabulary Word Walls, Personal white boards/dry erase markers, Engineering notebooks

6

LEAP: Novel Learning Experiences

Desert Tortoise Unit

- **Challenge**: Design and build a simulation of a desert-tortoise's (Gopherus Agassizii) behavior and its habitat
- **Resources**: Lego Mindstorms NXT kit, NXT software, additional Lego parts, Phoenix Zoo, AZ Game and Fish, Botanist, Herpetologist, Reference materials, Books, Internet sites
- **Materials** incorporated into the project as the student work evolved: found objects, plants, soil, rocks, water, raven sounds, black construction paper, toys (e.g., representing humans, buildings)

7

LEAP: Desert Tortoise Unit

- **Challenge**: Design and build a simulation of a desert-tortoise's (Gopherus Agassizii) behavior and its habitat
- Adult and baby desert tortoises were brought to the classroom
- Students went on a field trip to the Phoenix Zoo's Sonoran Desert Trail; visited the desert tortoise exhibit
- Interacted with a herpetologist and a botanist
- Print resources (Brennan & Holycross, 2006; Phoenix Zoo Newsletter on the Desert Tortoise)
- Byrd Baylor's books: *The Desert is Theirs*, Macmillan, 1975, and *Desert Voices,* Macmillan, 1981

8

LEAP: Desert Tortoise Unit Embedded Assessment

1. Your friend wants to look for a desert tortoise. To help her out, list items that can be found in the habitat of a desert tortoise.
2. Your friend doesn't really know what a desert tortoise looks like. Help your friend by listing physical features of a desert tortoise.
3. Before your friend goes out to look for a desert tortoise, you have decided to give her some information. Complete these sentences:
   1. A desert tortoise gets water by _________
   2. A desert tortoise digs a burrow with _________
   3. A desert tortoise uses a burrow to __________
   4. In its natural habitat, a desert tortoise eats _______
4. You have been asked to build a robot that acts like a desert tortoise. List the actions the robot should perform to act like a desert tortoise?
5. List the components (parts) your robot needs so that it can act

9

LEAP: Future Directions

Design-Based Research

- Refine novel K-12 engineering learning and teaching experiences
- Field-test novel K-12 engineering learning and teaching experiences in formal and informal settings; greater professional development for teachers
- Identify principles that define the novel experiences in specific contexts; Identify mechanisms that underlie the success of these novel teaching and learning experiences
- Conduct feasibility studies in different settings (rural, urban, suburban, formal, informal)
  - Eventually lead to innovations in STEM Education
    Sloane (2008) Table 1 (p 628)--focus on early phases leading to efficacy trials
- Sloane, F. C. (2008, December). Randomized trials in Mathematics Education: Recalibrating the Proposed high watermark. *Educational Researcher,* 37(9), 624-630.

10

LEAP: External Evaluation Design

Confirmation of Effectiveness; Scale-Up

- Greater use of curriculum within school system
  Focus on School System: Interest and Capacity to use the Curriculum
  Issues: Financial and political support of district leadership; Nature of professional development needed
  Building of infrastructure and teaching capacity
- Transfer of curriculum to Charter School, Boys and Girls Clubs
  Focus on different population of students, competing activities for students, relationship of clubs to community and parents
  Evaluation: Use of systems thinking and attending to systems dynamics

11

LEAP: External Evaluation Design

Sustainability

- Program Sustainability--continued in the school district beyond the life of the grant
- Sustainability of learning of participating students
- Sustainability of collaborations: How collaborations can continue to spur other innovations over time
- Sustainability of teaching capacity: Means of embedding teaching methods through district professional development to sustain capacity to use project curriculum

12

LEAP: External Evaluation Design

Fundamental Conceptual Shifts

- A key part of determining effectiveness, scalability, and sustainability involves attention to fundamental conceptual shifts.
- Shift from teacher-directed de-contextualized learning to student-engaged project-based learning
- Shift from fixed skills and knowledge as learning outcomes to desired outcomes that: students are actively engaged; develop capacity to explore and figure things out; use engineering design principles (i.e., iterate, understand impact of constraints and availability of resources)

13

Key Questions

- How can OST STEM programs design and implement their interventions to address sustainability?
- With the high concentration on accountability, how can project-based learning using 21st century technologies sustain innovation and innovative instruction in public schools to ultimately impact policy?
- How can OST STEM programs research and evaluate their interventions to address sustainability?

14

Key Questions

- **Consider at least the following aspects of sustainability**:
- **building bridges** between after-school and in-school instruction and curriculum
- **designing curriculum and instruction models** that can be **transfer**red to other OST setting
- **sustaining** the **interest** of students in STEM beyond the life of the program

15