Learning 21st Century Skills:

The Learning by Design Approach

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Learning by Design

- A Project-Based Inquiry approach to learning science and scientific reasoning; in the context of design challenges.
- Middle schoolers work on design challenges (requiring iteration) that require targeted science, scientific reasoning (designing experiments, interpreting data, using data as evidence, explaining, ...), collaboration, communication, design and planning, ...
- Such experiences situate targeted content and skills in contexts in which they are authentically needed (short-term goals)
- Skills and practices are repeated, and learners experience how valuable they are (long-term goals)
- Learners interpret their experiences productively by taking advantage of what middle school kids like to do -- show off. They make presentations to each other.
- They work in small groups, reflect in small groups, share with the whole class, reflect and debug as a class.

In LBD, science and engineering practices are learned while achieving design challenges

- Learners identify issues they need to investigate
- They design investigations, carry them out, interpret data, and report to each other on results
- They use what they learn to address the design challenge, making informed decisions that they justify with experimental data
- They question when what their experiments tell them is applicable, requiring reading about the science itself
- They apply the science they are learning to the iterative design of working artifacts

- Design challenges are engaging; embedded activities can encourage reflecting on, discussing, and interpreting what they're doing.

What we wanted kids to learn

- Project and design practices:
  - Understanding a project challenge
  - Planning, managing time, …
  - Aiming for solutions together with understanding
  - Specification, trade-offs, iteration, criteria and constraints, …
- Science practices:
  - Investigation with a purpose: identifying what needs to be investigated, carrying out an investigation well, judging trustworthiness of results
  - Informed decision making, reporting on and justifying conclusions, judging and using evidence well
  - Explaining scientifically
- Collaboration practices:
  - Teamwork, collaboration across teams, giving credit
- Science content consistent with middle school objectives

Case-Based Reasoning suggests a model for productively learning from experience

- A case-based reasoner moves around in the world attempting to accomplish its goals (and creating new ones)
  - It applies lessons learned in old situations to new ones.
  - Sometimes it succeeds in its endeavors; sometimes it fails.
  - When it fails, it attempts to explain what was responsible for the failure and updates its memory accordingly.
- It extends its knowledge by adding new cases; re-explaining, re-encoding, and re-indexing old ones; and abstracting out generalizations.
  - Expectation failure, explanation, and trying are key.

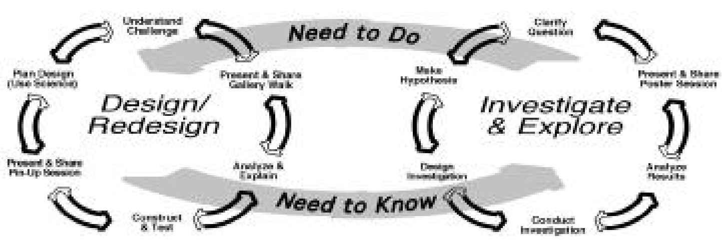
Promoting Learning: in a Nutshell

- Case-based reasoning provides suggestions about productive learning from experience
  - Case-based reasoners go into their experiences with personal goals -- short term and long term
  - They interpret their experiences to shed light on how to achieve their goals
  - Learning happens in the process of achieving short-term goals and readying oneself for achieving long-term goals
- We can help children learn by helping them
  - have personal goals related to the science and engineering we want them to learn,
  - have experiences that can help them learn the content and learn practices for achieving their goals, and
  - interpret those experiences to get the most out of them (content, process, practices)

What does it take to promote learning from experiences?

- For case-based reasoning programs:
  - Extract lessons from their experiences
  - Label (index) experiences by important feature combinations
  - Remember old situations
  - Apply lessons learned in new situations, adapting them to fit
  - Explain their surprises and failures
  - Modify lessons learned and indexes accordingly
  - Have enough experiences to apply and "debug" what they are learning (iteration towards understanding)
- Our idea: Design activities and ways of carrying them out so learners will do the same

LBD's Cycles



Vehicles in Motion
(My favorite LBD unit)

- Design and build a vehicle that can propel itself over several hills and beyond; the farther the better
  - Introduction to the challenge
    - Play with toy cars, identify what they know, generate questions they need to answer to achieve the challenge
  - Coaster Car Challenge
    - Friction and keeping things going
  - Balloon Car Challenge
    - Getting and keeping things going
  - Rubber-band and Falling Weight Challenge
    - Comparing different kinds of propulsion
  - Grand challenge hybrid-engine vehicle
    - Pulling it all together through application

Sequencing the Balloon-Car Challenge (Design and build a balloon-powered engine; make it go as far as you can on flat ground)

- Design challenge is posed.
- "Messing about" and then "whiteboarding" leads to question posing. *(Messing About)*
- Investigation following scientific methodology. *(My Experiment)*

- Balloon-car challenge
- W/balloon engines
  - Size of balloons?
  - Length of straw?
  - Diameter of straw?
  - Double balloon?
  - Double engine?
- Each group chooses a question and designs and runs an experiment

From Group Work to Class Discussion; From Phenomena to Science

- Sharing results in a "poster session"
- Drawing out design rules of thumb *(My Rules of Thumb)*
- Identifying more questions, reading to answer them, discussion, application, …
- Revising rules of thumb

- – Why were the results of that run so different?
- – Maybe you didn't blow up the balloons the same every time.
- – Two engines are better than one because ???
- – …
- – Combining forces, net force
- – The because is filled in.

Getting to Scientific Reasoning

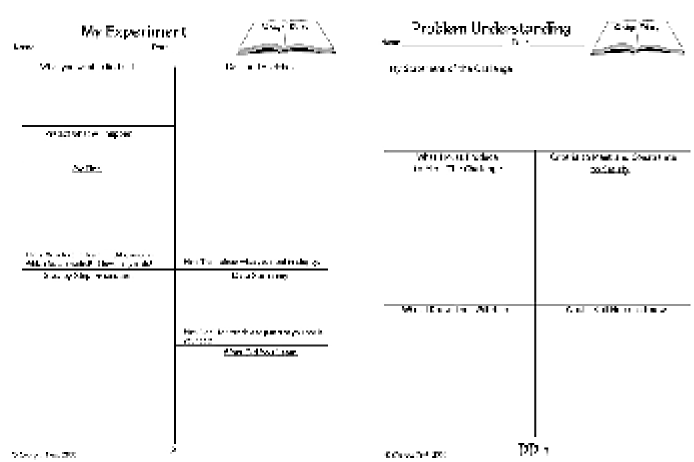
- Design planning
- Pin-up session *(Pin-up Notes)*
- Construction and testing *(Testing my Design)*
- Gallery Walk *(Gallery Walk Notes)*
- Need for more science and adjustment to rules of thumb (*My Rules of Thumb*)

- – Let's use two engines and double the balloons in each because …
- – We decided to use double-walled balloons because …
- – We also decided to use two engines because …
- – It doesn't work exactly as expected; e.g., the wheels spun out
- – The wheels spun out. … We don't know why.
- – Read text pages about …
- – Create new rules of thumb; revise old ones

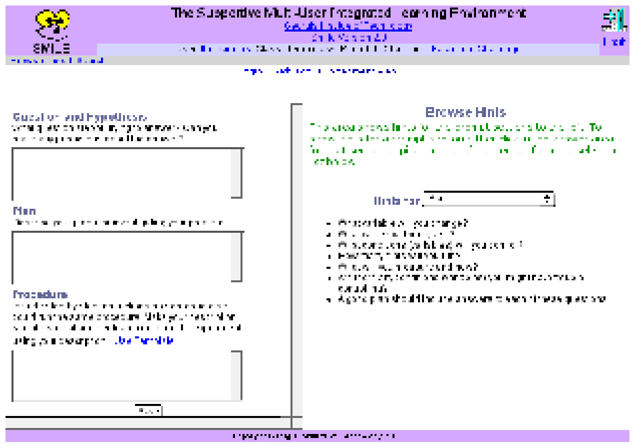
Summary; Pulling it all together

- Iterative refinement
  - Again and again
- Final gallery walk
- Product history
- Try something else; another gallery walk
- Individual and group writeups
- Application problems and scenarios
- What would happen on the beach with an engine like that?
- Lessons learned
- About science, science practice, collaboration, ...

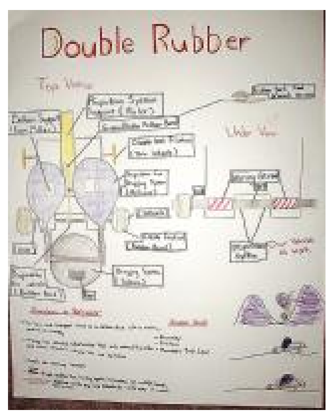
Two Design Diary Pages

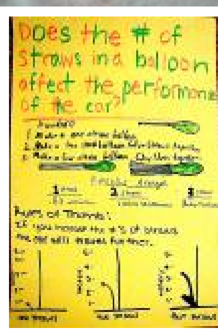


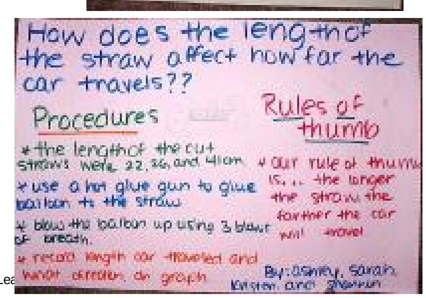
Experiment plan



LBD in Action







The teacher's role?

- Focuses kids, guides whole-class discussions
- Sets expectations
- Models behaviors, values, and attitudes
- Scaffolding and coaching

Results

- Comparisons show that LBD participants learn science at least as well, usually better, than peers; they more quickly get to work, knowing what to do; they move into collaborative work fluidly, whether working with a group they are familiar with or others
- Awareness, want, and appreciation of collaboration.
- Awareness, want, and appreciation of the need for rigor in collecting and using evidence, using the vocabulary of a domain, and justifying decisions. Some are aware of what's required for a rigorous explanation.
- Skills for engaging in these practices with some fluency, and they value their skills (e.g., science fair, poster and pin-up sessions, critiques of the investigations of others)
- Hold repeated activities "sacred" and invest in them -- personalizing and adapting them to their needs over time. They cannot imagine why others would not want to do (and learn to do) all of these things well.
- Many 21st century skills are appreciated and practiced.

Comparing LBD classes to each other, …

- We see significantly more growth in scientific reasoning capabilities and participation in scientific practices over the course of a year in classes where
  - students take seriously learning from peers and helping their peers learn (through sharing their experiences)
  - teachers push students to make their presentations and comments at a level of scientific rigor that allows students to connect science principles/concepts with experiences phenomena
- In those classes, many students think of themselves as "student scientists"
- In those classrooms, we think we see a culture of collaborative learning and rigorous scientific thinking

What makes it work?

- Small-group collaboration sequenced with whole-class presentation and discussion promotes reflection on experiences, public practice of complex skills, public debugging of complex skills
- Named and repeated scripted (as in Schank and Abelson, 1977) activity structures each provide a systematic way of carrying out important skill sets
- Launcher units introduce skills and scripted activity structures and promote development of a culture of collaboration and rigorous reasoning
- Design diary pages, student textbook that includes purposes of activities, hints, and coaching scaffolds successful participation in activities
- All in the big context of achieving a goal learners buy into and smaller contexts of need on the way to achieving that goal

Sample activity structures

- Gallery walk -- scaffolds explanation
- Pin-up session -- scaffolds justification
- Poster session -- scaffolds investigation and data interpretation
- Design rules of thumb generation-- scaffolds data interpretation
- Messing About and Whiteboarding -- scaffold question asking

Each corresponds to a set of targeted skills; each has goals, sequencing, ways of doing, and design diary pages associated with it.

How/why does the culture develop?

- Sharing with others is critical to the classroom practice
  - Students often need each other's investigative results; this provides reasons for making good presentations and listening to and assessing the presentations of others..
  - The need to present coherently encourages rich interpretation.
  - The felt need to give advice to others encourages anticipation of the difficulties others will have.
  - The need to understand applicability of the advice of peers encourages active listening, questioning of peers, and the drawing of lessons from presentations.
  - The need to teach others promotes real use of design diary pages as they do work in small groups and as they prepare to present.

Launcher Units introduce community practices and norms

- "Launcher units" gradually introduce practices of scientists and engineers, in the context of simple science, in contexts where their value and purpose are clear
- Many launcher activities emphasize the roles of individuals in the community, affording recognition of useful values
- Launcher units help kids recognize the similarities between the activities they are engaging in in the classroom and those scientists and engineers engage in
- The aim is for kids to recognize the value in practices first, and to develop competence in each over time
- Cultural norms we want to promote (values, practices, sacredness of some activities) are embedded in activities and their sequencing
- Teacher and text help students notice and appreciate the norms; name the practices and rituals; extract tactics, strategies, and values; and personalize them

Apollo 13: The Launcher Unit

- Book support challenge
  - We need each other's ideas to succeed; it's gratifying if we do; it's important to give and great to get credit; designers, scientists and engineers build on what others do; importance of tradeoffs, iteration, and defining project goals well
- Drops on a cookie
  - We need to be precise about what we are doing to come up with solutions; we need to explain well so others can replicate; results are gratifying if we do that
- Apollo 13 movie
  - Scientists and engineers really do all this stuff
- Tape
  - Being precise about experimental methods allows others to be able to use your results (and that's useful and gratifying); data derived from experiments provides evidence for decision making and allows persuasion
- Letter to the principal
  - Arguing a point requires justifying carefully with evidence; you can persuade someone that way
- Parachute challenge
  - When we decide together what we need to do, we can each be really creative and different anyway; we need each other for data gathering; we need each other for ideas; iterating toward a solution and iterating toward better understanding go hand in hand; precision …
- IDEO video and shopping cart challenge
  - Really cool designers do all this same stuff to succeed; it requires effort but is gratifying in the end; mistakes are necessary, so are dumb ideas; investigation is needed; iteration really is needed,…
- What have we learned about being scientists and engineers? What's useful about what we've learned?

Launcher Implementation Principles/Practices

- Reflecting together throughout
  - What have we learned about collaborating? What have we learned about designing? What have we learned about …? Which things do we want to continue doing? How will we make those things work? …
- Scientific reasoning and project and design skills are threaded throughout
  - Designing experiments, analyzing data, using data as evidence, making informed decisions, planning, piloting, iteration, …
- Activities build on each other
  - Each activity affords learning many things; each class articulates only some of its lessons; each child takes away some of those; connections are regularly made during discussions; experiences can be/are referred back to later to extract other of the lessons that can be learned from them.

Learning 21st Century Skills

- Adaptability -- learners work on multiple large challenges throughout a year and over several years; each time with a different small group; each one requiring different performances
- Complex communication and social interactions -- sharing during presentations, working around the project board together, needing each other in small groups, needing results of other groups, requires that challenges be complex enough that learners do, indeed, need each other

- Non-routine problem solving -- learners work on problems with many good answers, they share ideas and compare solutions; over a year or years, they experience much variety
- Self-management -- a key in LBD, and LBD supports learning to do this through Launcher Units, scripted activity structures that make sequencing second nature, scaffolding that helps learners be successful engaging in activities, and foregrounding of practices and reflection on them that helps learners examine what they are doing and how to successfully achieve their goals
- Systems thinking -- comes with the territory IFF you have learners working towards achieving challenges that require systems thinking, provide support for success, and foreground systems thinking when examining and debugging reasoning

Learning Complex Skills: Components

- Foregrounding of practices
  - Pushes kids to focus on how they are doing things, what works well, what doesn't
- Introduction through "launcher"
  - Helps kids understand the importance of practices and when each is used
  - Gives a first chance at using them and learning about them
  - Promotes creation of learning community and classroom culture
- Repeated public and reflective practice
  - Helps learners develop scripts (Schank & Abelson) that make sequencing feel automatic
  - Helps learners debug the way they do things
  - Provides learners opportunities to see how well they are performing
- All in a context of authentic need
- The whole system promotes a shift in the roles of teachers and students and the locus of initiative

Learning Complex Skills: Systemic view

- LBD's scripted activity structures and their sequencing provides a system of mechanisms that enhance each other
  - The activity structures and their sequencing combine cognitive affordances for learning to do and learning when to do with social affordances for participating in learning and for becoming
  - Many of the scripted activity sequences convey how-to's at the same time they convey values
  - Each scripted activity structure corresponds to a targeted skill (set) that students see a need to learn and that addresses both a learning need and an engagement need
  - No activities live in a vacuum; sequencing takes into account natural project sequencing, natural sequencing of targeted skills, and reflection/abstraction needs
  - Introduction to each scripted activity structure (in launchers) places early emphasis on kids recognizing a need, value, and purpose of each kind of activity
- Means sequencing needs to be designed carefully in advance

Are Design Challenges Required?

- A resounding NO.
- In PBIS (Project-Based Inquiry Science, collaboration with Joe Krajcik and others), we have integrated all of this into 15 units that cover middle school science.
- Some are design units (Diving In, Moving Big Things, Vehicles, Energy, Underground City, Genetics)
- Others answer an engaging big question (Ever-Changing Earth, Good Friends, Living Together)
- In all, kids investigate with purpose, require each other's ideas and advice, exchange ideas and reasoning publicly, discuss process, carry out skills and practices in contexts of authentic need, begin each year with a Launcher Unit

LBD vs. other approaches

- LBD students' gains are equal or better than those of comparison students on all topics covered by standard-format written tests, including content that receives greater focus in the comparison classes than in the LBD classes.
- LBD students' gains most often surpass comparison students in the target content.
- LBD classes perform significantly better than comparisons on science practices when engaging in performance assessment tasks that require students to work in groups to design an experiment.
- Average-ability LBD students perform as well or better than comparison (non-LBD) honors students on these same performance assessment tasks.
- Teacher expertise and class level play important roles in student gains for both comparisons and LBD students, but when teachers with high content knowledge and good inquiry-based skills are compared, students who used LBD master the content at a much deeper level than students using other learning materials.

Types of activity structures

Each has goals, sequencing, ways of doing associated; each corresponds to a set of targeted skills;
each has design diary pages associated

- Small group
  - Planning
    - Designing an experiment
    - Planning a design
  - Doing
    - Messing about
    - Running an experiment
    - Testing a design
  - Reflecting/abstracting
    - Rules of thumb
- Whole-class
  - Presentation/discourse/reflection
    - Poster session
    - Pin-up session
    - Gallery walk
  - Reflection/abstraction
    - Whiteboarding
    - Rules of thumb
- These tend to become ritualized