Learning by Design: How we got there and what can be learned from the effort

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So many things I can talk about ;-)

- How to use what we know about learning to design ways of helping people learn
  - The design of Learning by Design
  - Software to support design-based, project-based, problem-based inquiry learning (60)
  - Project-Based Inquiry Science – 3 years of curriculum (79)
- How to make what you've designed work (32)
  - Easing learners into it – Launcher Units and repeated deliberative practice
  - Creating culture – both theory and practice

We began with problems in science education and the audacity to think we could address them (1994)

- Kids don't see the relevance of science to their lives, so many never engage.
- Learning science concepts can be difficult, so many youngsters easily become disengaged.
- Teachers in middle school (grades 6 to 8; end of primary school and beginning of secondary school) do not always know the science they are teaching, so it is hard for them to make it engaging or deep.
- Most textbooks present science as facts; but science is done by people and is a way of thinking.

Goals we wanted to achieve

- Deep learning of science content for everyone
  - Not just the "good students" and those already interested in science, and not just the ones who understand easily
  - Not just among students of teachers who understand the science well
  - And without boring those who understand easily
- Learning of science skills and practices, nature of science, 21st century skills, and science and technology connections; all without sacrificing deep understanding of science content
- Appreciation of science's value and disposition to think scientifically
- Sustained motivation to engage
- Later: Coverage of 3 years of standards-required content, skills, and practices

Our Answers

- Integrate learning of content and reasoning with each other by having learners learn them in a context of authentic use.
  - Authentic? Content is used and reasoning is done in contexts where they are actually needed
- Make the classroom a place for addressing challenges together -- solving problems and/or achieving design challenges.
- Make it interesting; choose challenges wisely; help learners become interested in each challenge and remain engaged with the challenge.
  - Wisely? Potentially interesting to learners, can be used to cover a good chunk of content, trade-offs needed
- Grab opportunities for learning from the experiences learners are having.
- Vary the experiences, but be consistent with the practices
- Use what we know about how people learn to help students learn from those experiences.

How we got there: Case-Based Reasoning

- A case-based reasoner moves around in the world <u>attempting to accomplish its goals</u> (<u>and creating new ones</u>)
  - It applies lessons learned in old situations to new ones.
  - <u>Sometimes it succeeds in its endeavors; sometimes it fails.</u>
  - 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

- 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)

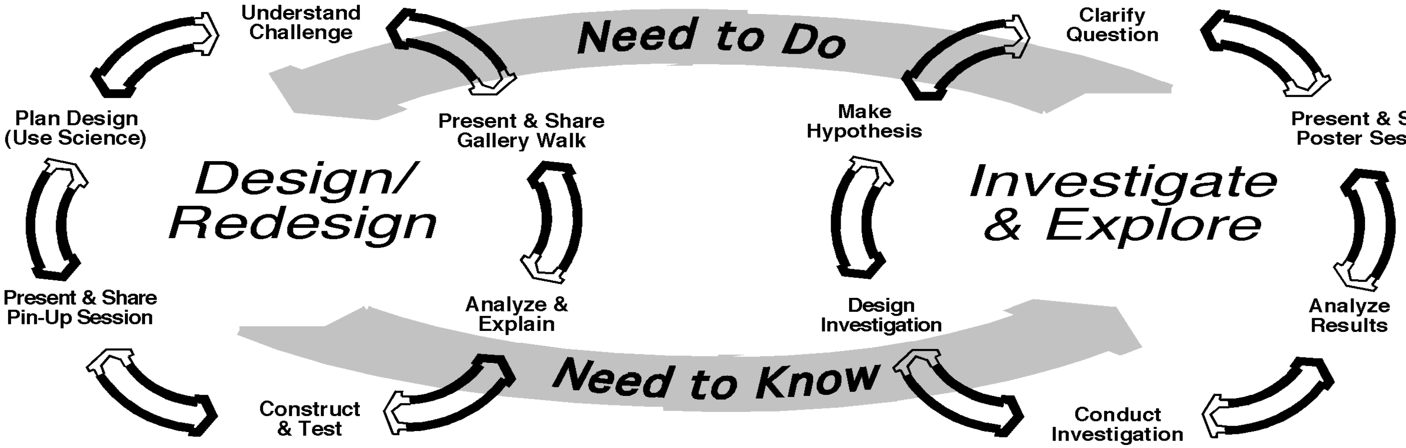
How can you manage all this in the classroom?

- My idea -- 20 years ago
  - Engage learners in a sequence of design challenges -- designing working devices.
  - Help learners take advantage of design's affordances for promoting learning.
  - Use the design challenge to promote interest in learning the science and need to carry out science, engineering, communication, and collaboration practices.
  - Design is by nature iterative; when a design solution doesn't work, it means there is something the learner doesn't understand or did not reason through or do well; iteration towards working solutions and iterations towards better mental models can happen hand in hand.
- But we knew nothing about classrooms ;-)
  - We learned fast ;-) and we built on Problem-Based Learning

The result was Learning by Design

- A project-based, problem-based, inquiry approach to learning science and scientific reasoning; in the context of design challenges.
- Middle schoolers work in groups 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.
- Sequencing and teacher facilitation promote reasoning needed to learn from experiences.

LBD's Cycles



Sequencing and teacher facilitation are designed to:

-sustain inquiry and enthusiastic engagement over the many weeks

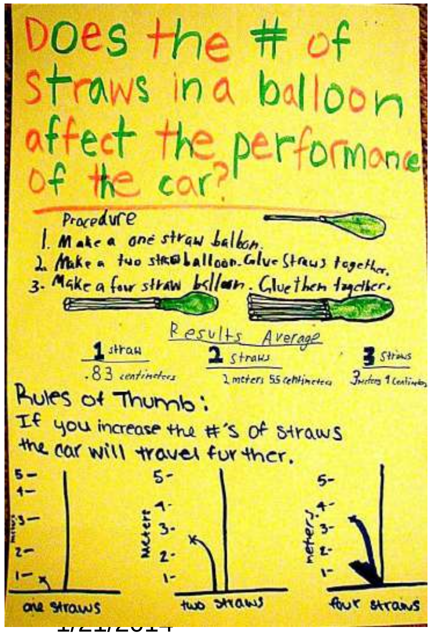
-promote progressively better understanding and capabilities

-promote reasoning needed to learn from experiences.

A typical project cycle

- Challenge is presented
- Messing about (in small groups) to generate questions for inquiry and discussion around a public whiteboard
- Investigation (distributed among small groups) to address questions followed by a poster session during which they report results to their peers; science reading to explain
- Design planning (in small groups)
- Pin-up session -- presentation of design ideas and the reasons for them to peers
- Construction & testing (in small groups)
- Gallery walk -- presentation of what happened, chance for help explaining why and figuring out how to move forward
- Additional investigation, demo, reading, discussion of content, redesign
- Iteration over last three steps
  - Learners iterate toward better understanding and toward better solutions at the same time.
  - Paper and pencil or software scaffolding accompany each small group activity
  - Learners go through this cycle 4 to 6 times over 4 months.

LBD in Action



Notice …

- Lots of different opportunities for sharing with the class
  - Other kids want their results
  - Kids want advice from others
  - They have the opportunity to get help
  - They quickly take charge and set themselves to making presentations that get results and give them credibility
- Opportunities for repetition
  - They get to retry with better skills and knowledge
- Questions are raised before activities are engaged in
  - Every activity they engage in has a purpose with respect to addressing the challenge
  - Investigation with a purpose, reading with a purpose, demos with a purpose, learning wth a purpose, …
- Reading and telling only after experiencing

Conventions

- PBL Whiteboard – what we know, ideas, questions
- Public presentations
  - Gallery Walk-- scaffolds scientific explanation
  - Pin-Up Session-- scaffolds justification with evidence
  - Poster Session-- scaffolds investigation, data interpretation, learning about trustworthiness of data
- Embedded Formative Assessments
  - Rules of Thumb/Create your Explanation -- scaffolds data interpretation and explanation creation
- AND ONE MORE THING I DIDN'T TELL YOU ABOUT: Launcher Units – to introduce community practices and norms

- Each convention has a purpose, sequencing, place in the sequencing, and ways of doing

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 <u>recognize the value in practices first</u>, and to develop competence in each over time
- <u>Cultural norms</u> we want to promote (values, practices, sacredness of some activities) <u>are embedded in activities and their sequencing</u>
- <u>Teacher and text help students notice and appreciate the norms</u>; name the practices and conventions; extract tactics, strategies, and values; and personalize them

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? … (there's something personal in this articulation based on experience, I think)
- 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.

Diving In: 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; science of structures
- 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
- Whirlygig challenge
  - 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
  - Scientists explain the best they can given what they know
  - Gravity and air resistance; combining forces
- 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 …
  - Gravity and air resistance; combining forces
- 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?

In the aggregate, it works!!!

- Kids learn science content at least as well as matched comparison kids with the best teachers
- LBD students in standard classes are indistinguishable from honors students who did not do LBD
- Kids learn practices of scientists, and they engage enthusiastically and with purpose
- AND kids think about themselves as student scientists, and they stand tall as they engage in classroom activities and explain to others

Classrooms look a lot different than more typical inquiry, project-based, or design-based classrooms

- Kids have an awareness, want, and appreciation of the need to collaborate.
- They have 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.
- They have some skills for engaging in these practices with some fluency, and they value their skills (e.g., science fair, investigation expos and plan briefings, critiques of the investigations of others)
- They remember and are proud of what they've learned.

The Big Question: How do you repeat that kind of success?

- For that, you need to understand why it is working ;-)
- We have a lot of explanations. For the moment, I leave that to you. Why do you think it works?
  - It's not because the teachers or students are better; explanations should use what you know about learning (writ large)

Cognitive explanation

- Learners have experiences worth learning from and that are interesting to them:
  - Projects (design challenges) require targeted science, scientific reasoning (designing experiments, interpreting data, using data as evidence, explaining, …), collaboration, design and planning, …
- They interpret their experiences to extract lessons and their conditions of applicability
  - Experiences situate targeted content and skills in contexts in which they are authentically needed
  - Specially-designed classroom activity and discourse structures promote extraction of lessons learned
- They get chances to apply what they've learned and debug the lessons they've extracted
- Iteration promotes debugging understanding, repeatedly reasoning scientifically, repeatedly collaborating and communicating, and experiencing the value of better understanding content and carrying out practices well.

What helps students build mental models?

- Framing first, details later -- Collins
  - Help students form the frameworks for mental models, then help them fill them in, revise them, and connect them.
- Help learners experience results of their decisions; help learners interpret those results and use them to debug their reasoning and understanding; repeat over and over again -- *repeated deliberative practice*
  - deliberative practice includes reflection on, articulation of, and debugging of reasoning (interpretation)
  - Repeated means having recurring opportunities to try out, troubleshoot, and revise understanding
- Lead students to wonder by asking questions; the book, the teacher, and peers can play this role
  - Allows learners to notice, allows learners to identify what they do and don't understand. Promotes identifying holes in one's mental models and generating questions
- Tell only when learners are ready to have answers, and allow students a role in telling their peers.
- Help students care enough (have goals) to put in the mental energy to construct and revise mental models.

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 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
- Work pages, student textbook that includes purposes of activities, hints, and coaching scaffold successful participation in activities and learning from experience
- All in the big context of achieving a big goal learners buy into and smaller goals that need to be achieved on the way to achieving that goal

Why these Results?

- Sequencing helps kids build mental models -- iteration towards understanding in a context of need
- Sequencing helps kids remain engaged.
- Launcher Units promote collaboration and getting to know the rules of the game
- Public practice gives them a chance to debug their reasoning skills and knowledge
- Public practices gives them a chance to "position" themselves (and others) with respect to content and practices
- Public practice gives opportunities for addressing every student's ZPD
- They expect things from each other.

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

Classrooms become scientific discourse communities

- Investigations have shown significant gains in abilities to design experiments, judge trustworthiness of evidence, argue, and explain.

- A culture of collaboration and rigorous science talk develops in classes where the teacher "trusts" the curriculum and the kids. Kids engage as and "feel like" student scientists when this culture is developed.

Culture and cognition develop together

- Adoption of ritualized activity structures seems to promote learning of cognitive skills
- Sharing with others seems to be critical to that development
  - 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 "felt need" to teach others promotes real use of design diary pages as they do work in small groups and as they prepare to present.

Learning Complex Skills: Systemic view

- PBIS's activity structures and their sequencing provides a <u>system of mechanisms</u> that enhance each other
  - The activity structures and their sequencing <u>combine cognitive affordances for learning to do and learning when to do with social affordances for participating in learning and for becoming</u>
  - 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

Caveat

- We don't yet know to what extent kids will be drawn to try to sustain practices and values over time;
- We suspect that one year of practicing within the culture isn't enough to widely sustain those practices and values when school doesn't match
- Now that we have a 3-year curriculum, we may someday be able to collect data to find out the extent to which 3 years makes such a difference

Slides about Culture

Culture … Hm…

- Shared values, practices, and ways of doing that participants value enough to want to sustain

Why do we talk about culture?

- Students walk around the room with the purpose of learning from each other
- Students take the initiative to use resources around the classroom (e.g., posters on the walls)
- Students give of their time to help others in the class
- Presentations are serious, aimed toward helping others in the class learn what they have learned
- Students challenge other groups' results and justifications
- Presentations are taken seriously as times to get advice from others
- Work toward achieving challenges is mostly cooperative across the class until everyone is on their way to success
- Kids take for granted the need to justify their decisions, explain all of their data, and so on.

It looks like culture

- Kids have an awareness, want, and appreciation of the need to collaborate.
- They have 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.
- They have some 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)

We designed for culture creation

- LBD units repeat scripted activity sequences associated with important scientific reasoning practices.
- LBD sequencing interweaves doing and reflection and gives chances to apply and debug newly-learned skills and content.
- "Launcher units" introduce practices of scientists and engineers. They have in them affordances for learning the scripts associated with participating in important science and design practices
- 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

A really good trick: Named and repeated scripted activity structures

- Each provides a systematic way of carrying out some important skill set
  - systematizes practices to make them methodical; promotes habits
  - situates practices in several contexts; promoting adaptability
  - engages students in public practice as collaborators; affording noticing, asking, discussion, productive reflection
  - repeated consistently; becoming a cultural artifact

An even better trick -- Whole-class scripted activity structures become ritualized

- 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 has goals and sequencing and ways of doing associated with it.

What's a "ritual"?

- In its best sense, a "ritual" is an important, named, "understood," and personally-meaningful script
  - supports ways of doing
  - has artifacts (epistemic forms?) associated
  - has context of use associated (when)
  - participants understand purpose
  - conveys values
- These are the ones kids invest the most in -- personalizing them and adapting them to their needs over time -- this is what we mean by "ritualizing"

Types of activity structures

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/abstr
    - 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

Two Design Diary Pages

My Experiment

Design Diary

Name ______________ Date ________

What you want to find out

Predict what will happen

My Plan

Hints: Which variables are held constant? Which factors varied? How many trials?

Step-by-Step Procedure

Data and Sketches

Hint: Think about what you need to display.

Data Summary

Hint: Look for trends and patterns you see in your data.

What Did You Learn

2

Problem Understanding

Design Diary

Name ______________ Date ________

My Statement of the Challenge

What I Must Produce to Meet The Challenge

Criteria to Meet and Constraints to Satisfy

What I Know That Will Help

What I Still Need to Know

DD 1

LBD's other best trick: Launcher Units introduce community practices and norms

- Their content focus is on "familiar" science; they use easy science and science kids already know in the context of activities that require collaboration, project/design, and scientific reasoning practices
- Sequencing of activities introduces practices gradually and always in contexts where their value and purpose are clear
- Important science practices are embedded into scripted activity structures that the text names and introduces as needed. They are repeated and serve as objects for reflection and deliberation.
- 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, ritualized activities) are embedded in activities and their sequencing and enactment
- Teacher and text help students notice and appreciate the norms; name the practices and rituals; extract tactics, strategies, and values; and personalize them

The Book Support Challenge

- Our goals: Help the class
  - come to appreciate collaborative learning
  - begin becoming proficient at vocabulary and practices of design
  - learn about the gallery walk
- Challenge: Design and build a structure that will hold up a large textbook 3 inches above a desk using only index cards, paper clips, and rubber bands.

Book Support Challenge: Iteration 1

- Short discussion of the challenge
- Students work in groups (10 - 15 minutes) to achieve the challenge.
- The class reads about "gallery walks" together.
- Each group presents their design to the class; each is tested, and there's some discussion.
  - Some students talk about strong structures they've seen that they got ideas from, some talk about the criteria they were trying to achieve -- e.g., making it flexible for different size books, making it sturdy. There is usually argument about whether making it flexible was in the challenge or not and just how sturdy it needs to be. There might be discussion about whether the supports were all tested the same way.
- The class may or may not revise the list of criteria.

Book Support Challenge: Iteration 2

- The teacher asks students if they want to try again.
- Students try again (this time working significantly longer than 10 or 15 minutes).
  - They are beginning to feel invested and competitive.
- They hold another gallery walk.
  - Students have always borrowed ideas from their peers, and they almost never give them credit.
- During or right after the gallery walk, students begin to accuse each other of copying.

Iteration 2: An opportunity for learning

- The teacher introduces students to the notion of building on the work of others, and to patents, citations, and they read in the text about collaborative learning and its benefits and requirements (e.g., giving credit)
- They talk about how their peers' ideas helped them, how they built on each other's work, and how when they get credit it doesn't feel so much like copying anymore. Some disagree.
  - They might talk about designing -- what did they do when they designed; how did they know if they were getting to a good solution -- the vocabulary of "criteria" and "constraints" is introduced; how their peers' ideas helped.
- They revisit the notion of the gallery walk and update their notion of how to participate.

Second Book Support Challenge

- Our goal: another chance to design, a chance for giving each other credit, a chance to recognize the usefulness of scientific understanding in designing
- Challenge: Make your bookstand appealing to buyers but not too expensive to produce.
- As a class, they identify criteria and constraints and discuss the challenge.
  - Questions arise about support structures and forces. Why did some ways of designing work better?
- Students read from their texts to understand support structures a little.
- They work in groups to attempt solutions.
- Gallery walk, comparisons, discussion of support, iteration
  - this time giving credit to each other for ideas and beginning to justify their decisions using the science they've read
- When done, revisit design and collaboration and LBD (the role design might play in learning)

The Apollo 13 Movie

- They see scientists and engineers engaging in the same design, science, and collaboration practices they've been engaging in.
- In their discussions of the movie, some kids begin to use the words iteration, criteria, constraints, variable, trial, collaboration, credit, …
- They compare what the scientists and engineers did and what they did
  - They refer back to their own experiences
  - In some classes, there are charts on the wall of how to engage in important practices; those are revised
  - They identify the usefulness of the practices

Over time …

- Sequencing, tricks, rituals, … are repeated; kids work in groups on projects, write up an individual lab report and/or product history for each module
- With each unit, in all LBD classrooms
  - The quality of kids' participation in science and collaboration practices improves (e.g., they get better at justifying decisions, critiquing a dataset, interpreting trends in data)
  - The kids' initiative in engaging in science and collaboration practices improves
  - The forms of the scripted activity structures are revised/adapted (kids and teacher participate in this)
- In some classrooms (where the teacher models the values and attitudes listed?), after each unit
  - more kids (but not all) take on the values and attitudes listed above
  - more kids (but not all) engage as student scientists
  - some kids begin to define themselves as scientists

The kids seem to launch a culture

- In most real-world situations, we bring a few people at a time into a culture that exists. There's a need in the classroom to get the culture started and do it in a reasonable amount of time.
- What happens during the launcher:
  - Kids live together; learn together; emote together
  - Kids decide what's important together
  - Kids discuss together; interact together
  - Kids model for each other; teach each other; explain to each other
  - Kids notice together (and articulate) what's fun and/or useful (and when), and decide (consciously or unconsciously) to continue to do those things
  - All happens repeatedly, building on shared experience and sharing individual experiences

The kids identify some practices as particularly important and adapt the scripted activities to emphasize those they've chosen

- Critiquing
- Advising
- Listening (reading)
- Aiming to understand
- Reporting
- Questioning
- Getting to the causal mechanisms behind phenomena

- They tell each other (and us) what's important and why; it's not exactly the same in each class; they argue about whether the challenge or learning the science is more important

Vehicles in Motion

A favorite unit: Vehicles in Motion

- 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, keeping things going, keeping things going in a straight line
  - 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
- Units begin with a big challenge, learners raise questions, each module addresses some of those questions, between modules they revisit the big challenge

Getting Started with the Balloon-Car Challenge (Design and build a balloon-powered engine; make it go as far as you can on flat ground (They've already focused on "straight".))

- 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"
  - Why were the results of that run so different?
  - Maybe you didn't blow up the balloons the same every time.
- Drawing out design rules of thumb *(My Rules of Thumb)*
  - Two engines are better than one because ???
  - ...
- Identifying more questions, reading to answer them, discussion, application, …
  - Combining forces, net force
- Revising rules of thumb
  - 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*)

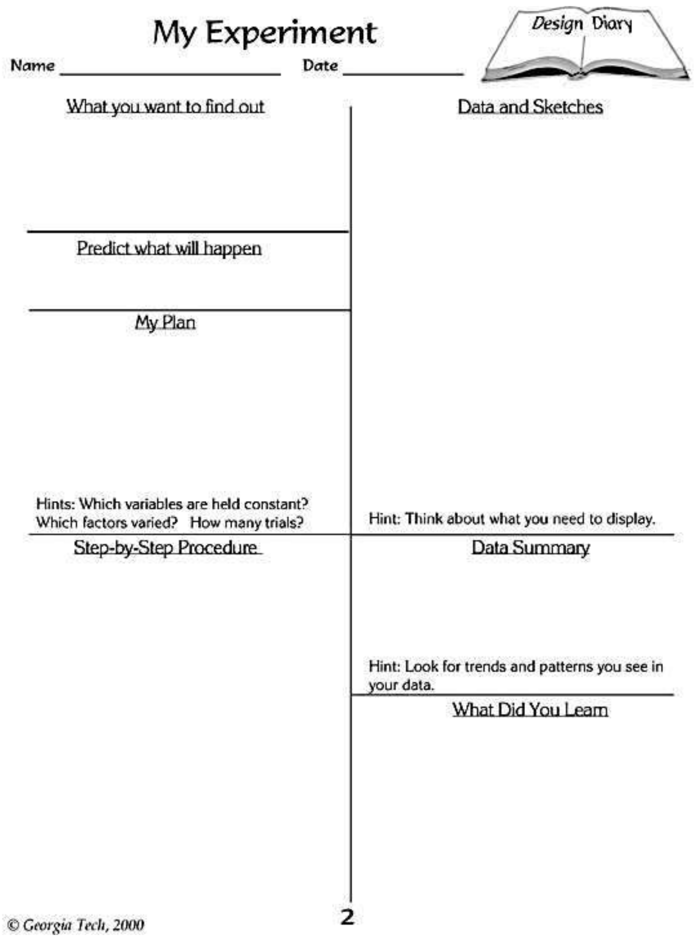
- Let's use two engines and double the balloons in each because …
- We decided to use double-walled balloons because …
- We also decided to use two engines because …
- It doesn't work exactly as expected; e.g., the wheels spun out
- The wheels spun out. … We don't know why.
- Read text pages about …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

Pulling it all together, application, and sustaining context

- Iterative refinement
  - Again and again
- Final gallery walk
- Product history
- Application problems and scenarios
- Lessons learned
- Back to the Big Challenge

- Try something else; another gallery walk
- Individual and group writeups
- What would happen on the beach with an engine like that?
- About science, science practice, collaboration, ...
- How can we apply what we learned to the challenge; what else do we need to learn?

Some reasoning aids



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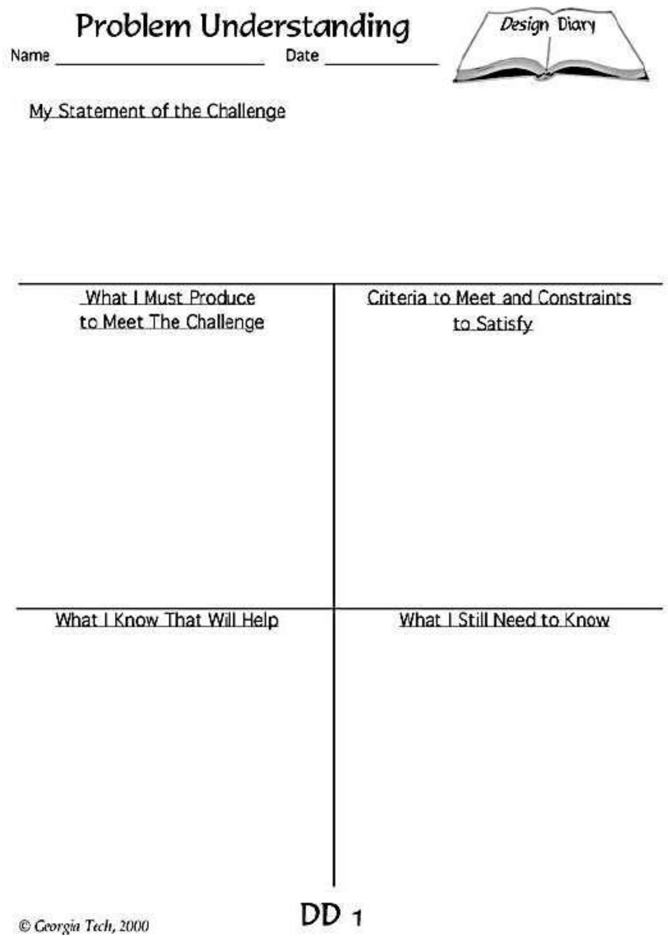

Problem Understanding

Design Diary

Name ____________ Date ________

My Statement of the Challenge

What I Must Produce to Meet The Challenge

Criteria to Meet and Constraints to Satisfy

What I Know That Will Help

What I Still Need to Know

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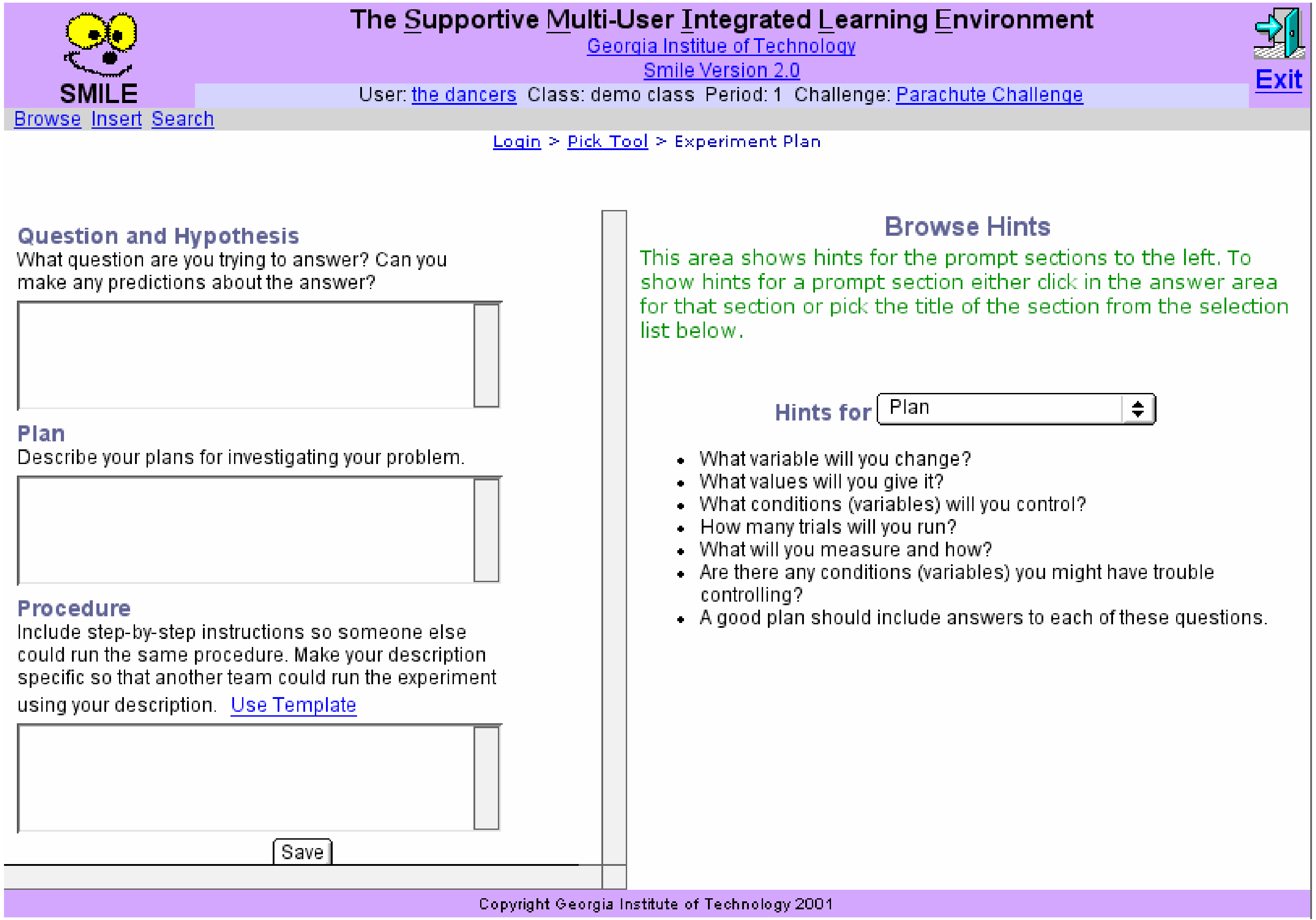
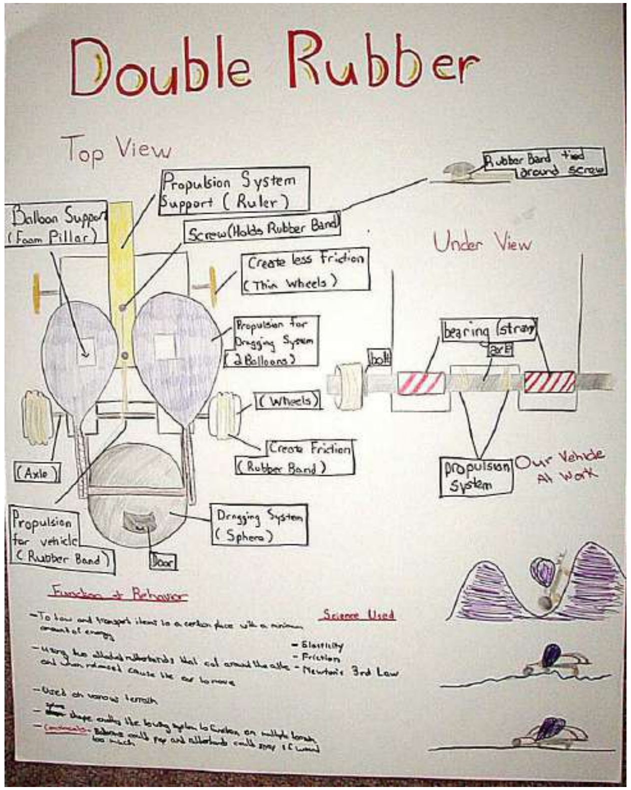
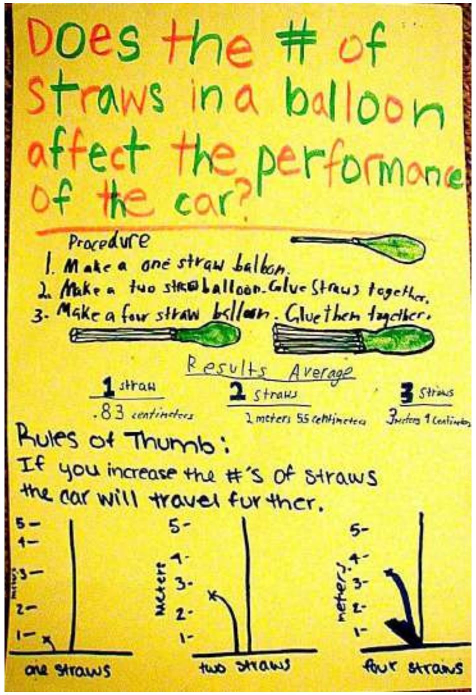
DD 1

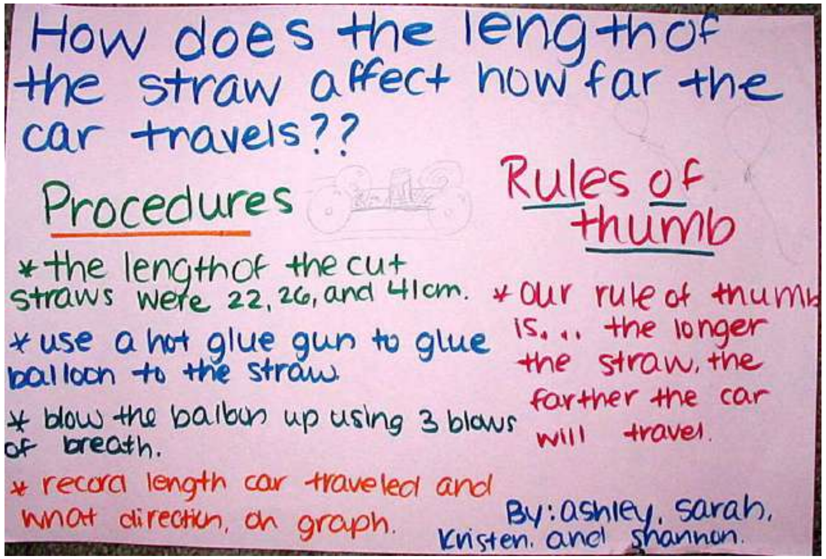
And some on the computer



Some products …







Roles for Technology

It works in the aggregate, but it could address individuals better

- Kids don't collaborate real well in small groups when things get difficult
- The physical models they build are limiting wrt learning quantitative aspects of science content
- All the iteration on physical models they build takes a tremendous amount of time.
- While all the literatures predict and account for the trends in our results, they don't predict or explain the individual differences in students' development of capabilities.

These realities of the world suggest new roles for computing

- Can we use the computer to help kids interact in their small groups when the teacher isn't available to facilitate? SMILE
- What would it take for computer modeling and/or simulation systems to help with quantitative understandings and/or with limitations imposed by time? Vehicles modeling and simulation
- Can we design computer models of distributed cognition to help us understand the individual differences in students' learning? Not there yet.

Helping small groups interact

- SMILE (supportive multi-user interactive learning environment)
- Designed to provide scaffolding for students working together in small groups
  - Designing an investigation; interpreting data; presenting results
  - Making and justifying design decisions
  - Keeping track of design iterations

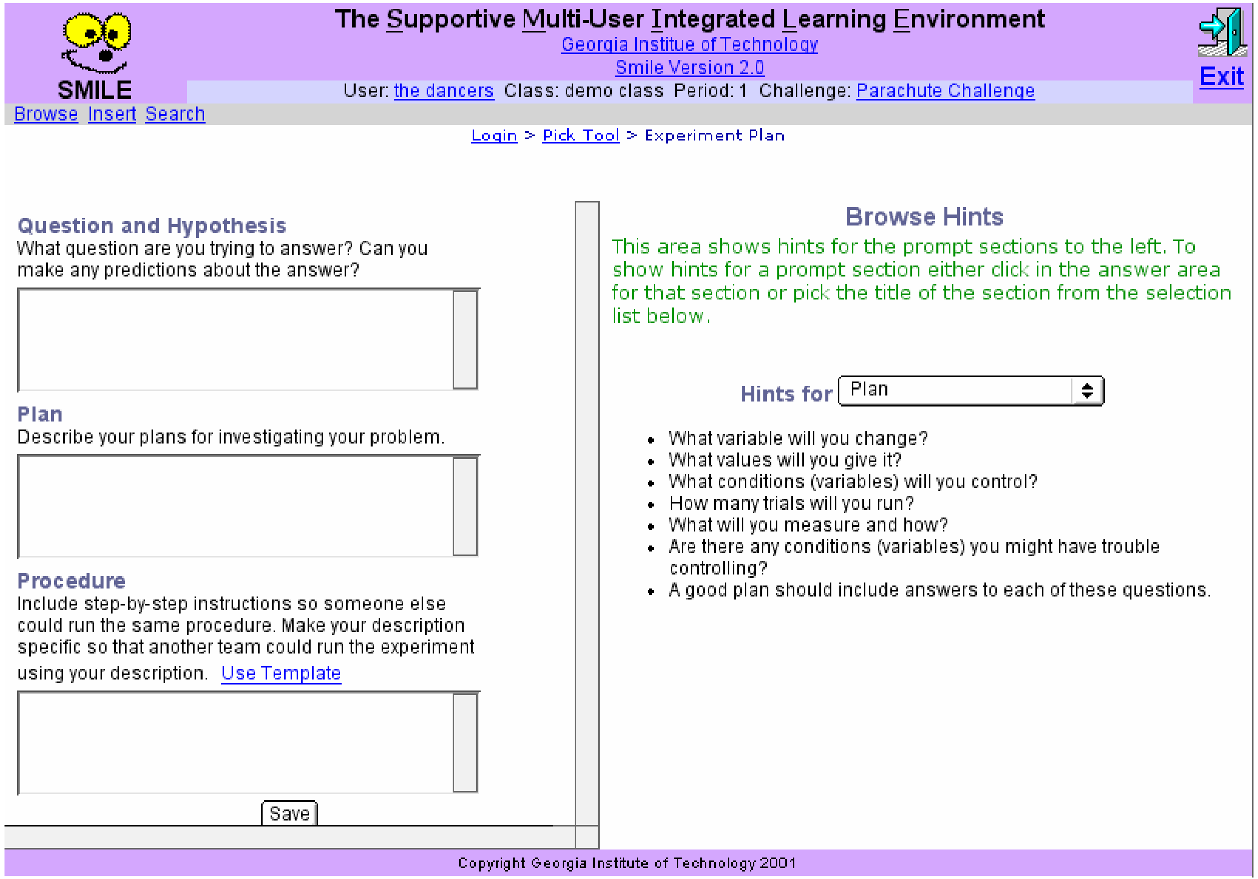
Designing SMILE

- Required considering what kids needed help with, how that help could be most "naturally" integrated into their activities, the kinds of situations when it would make sense to be sitting around a desktop computer, how many computers in the classroom, …
- We wanted each of SMILE's "modules" to be consistent with its other modules

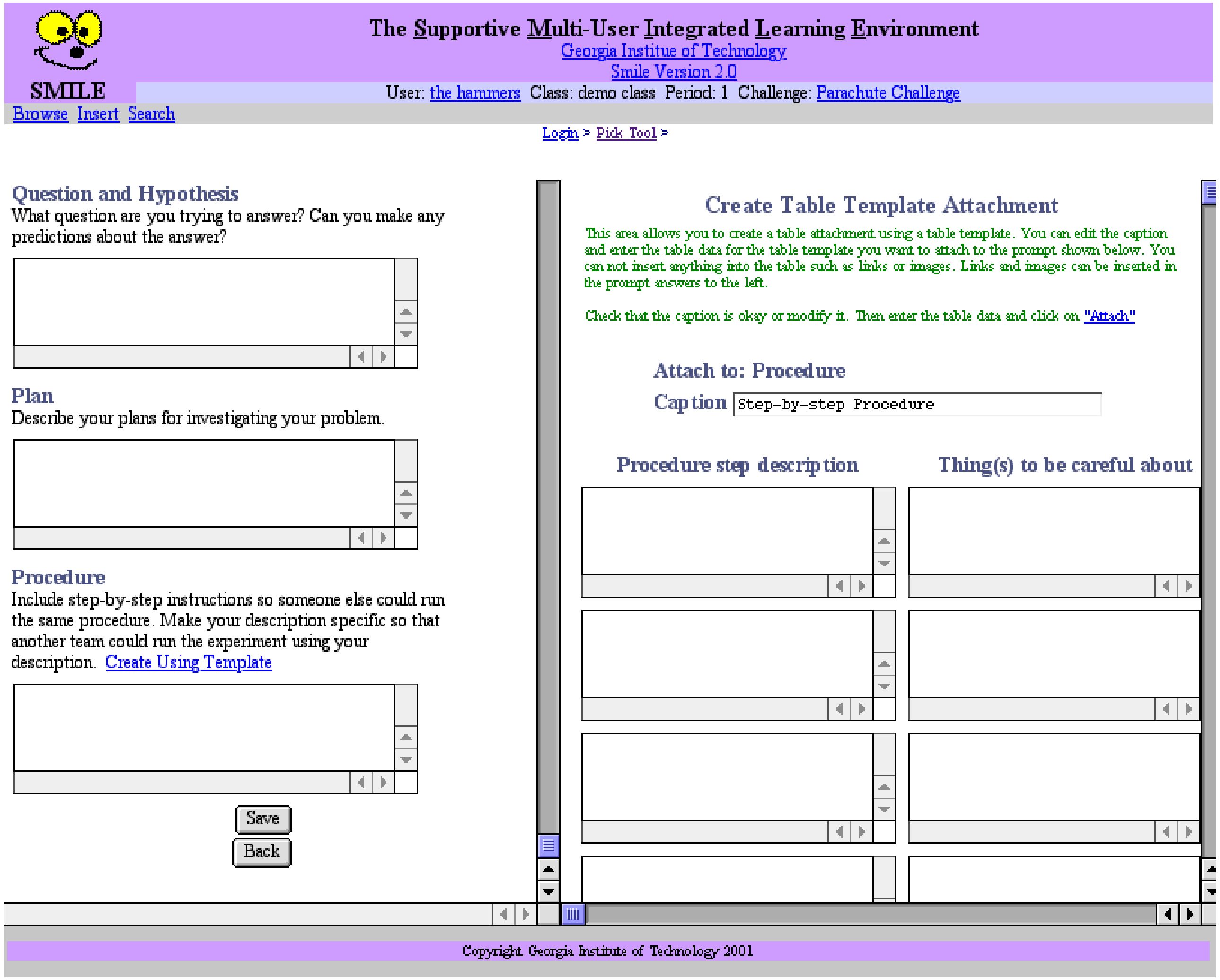
SMILE's scaffolding

- We designed SMILE as a "master" in a cognitive apprenticeship, sharing the job of "master" with the teacher.
  - The teacher models practices and skills for the class and coaches and provides other help while the whole class engages together;
  - SMILE provides the same help while kids work in small groups.
- SMILE's help comes in 5 varieties
  - Structuring of a task (what things do we need to think about in what order?)
  - Hints for each part of the task
  - Examples to go with each part of the task
  - Templates for specialized pieces of tasks
  - Sequencing of tools matches sequences of tasks

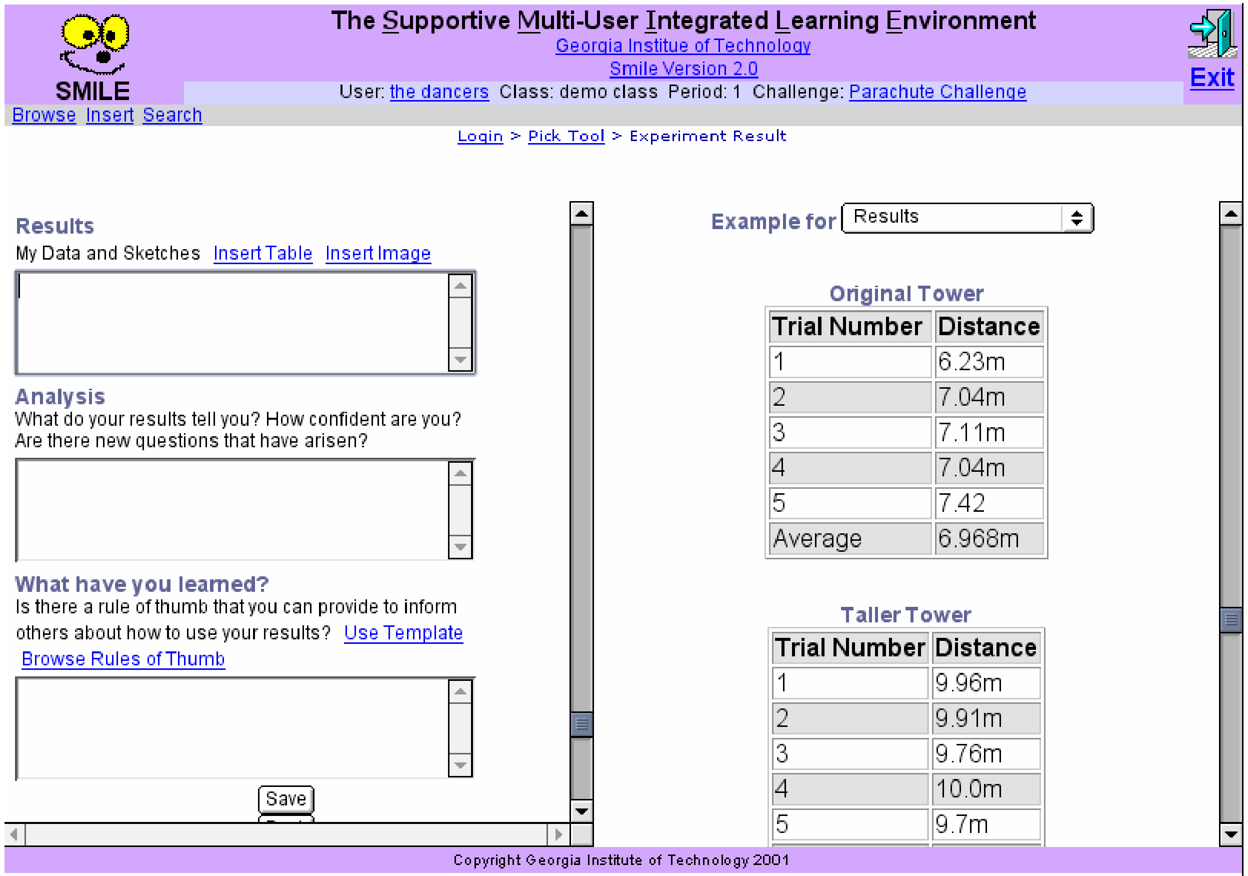
Experiment plan



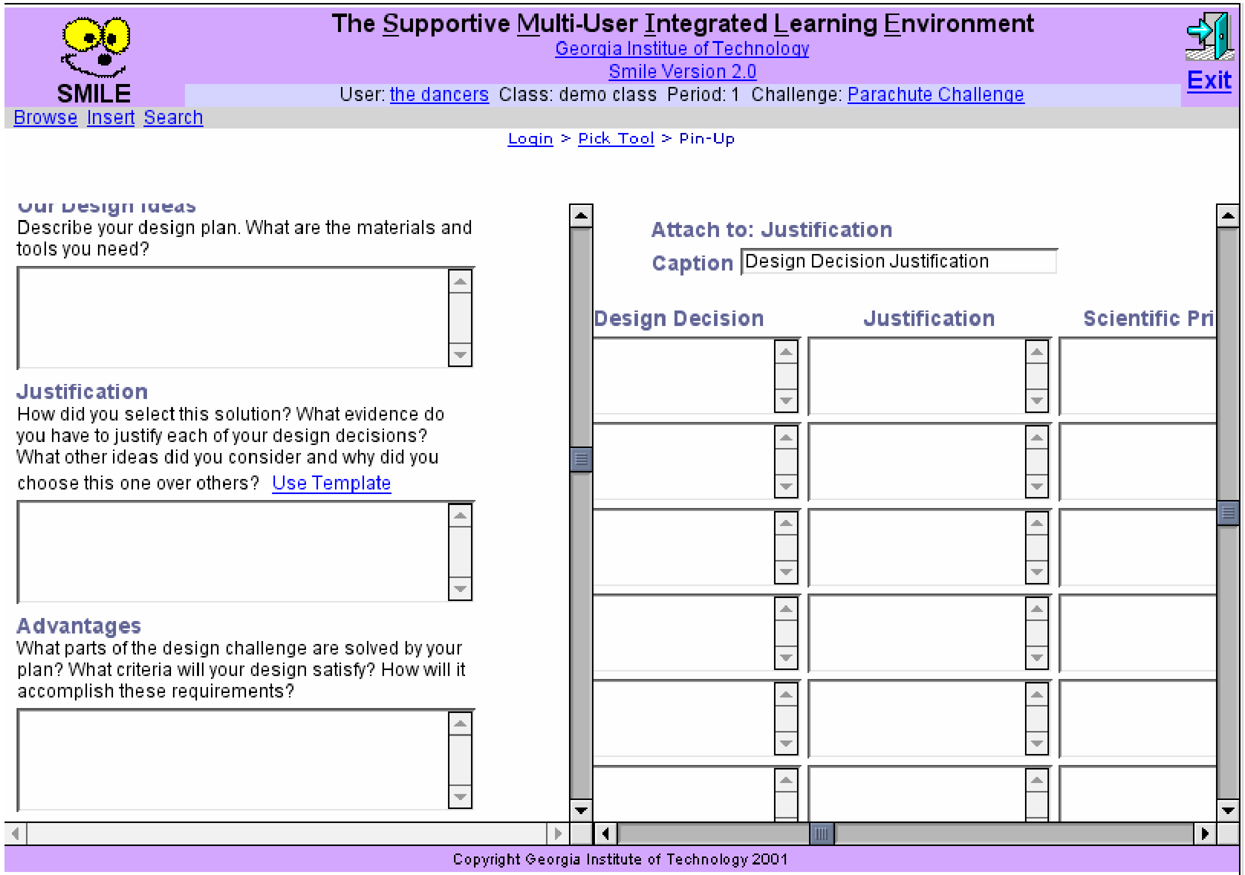
A procedure template



Experiment Results



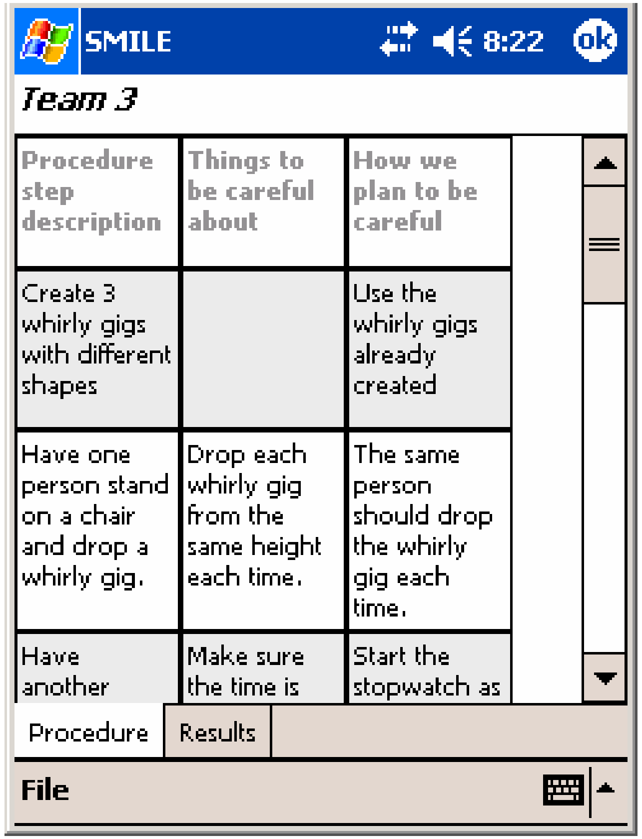
Design Planning

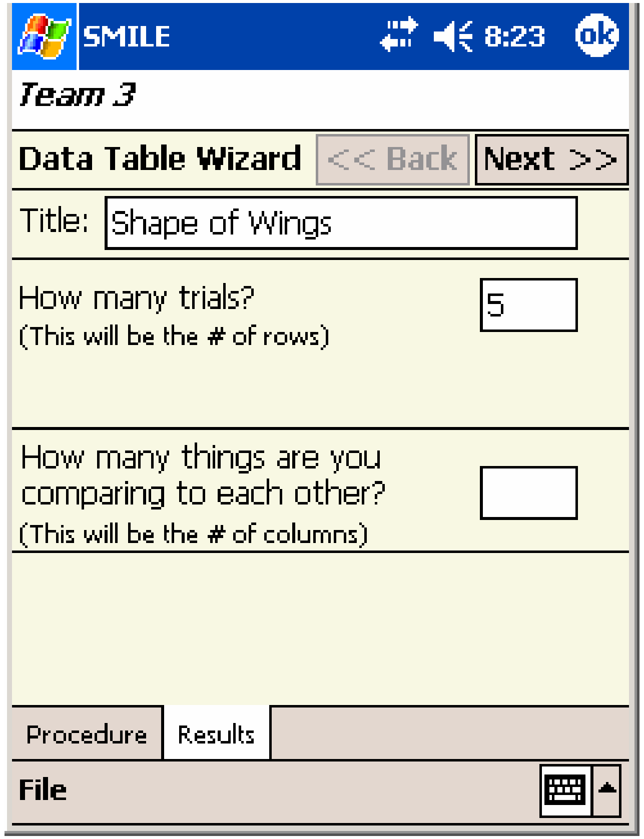


How is SMILE used?

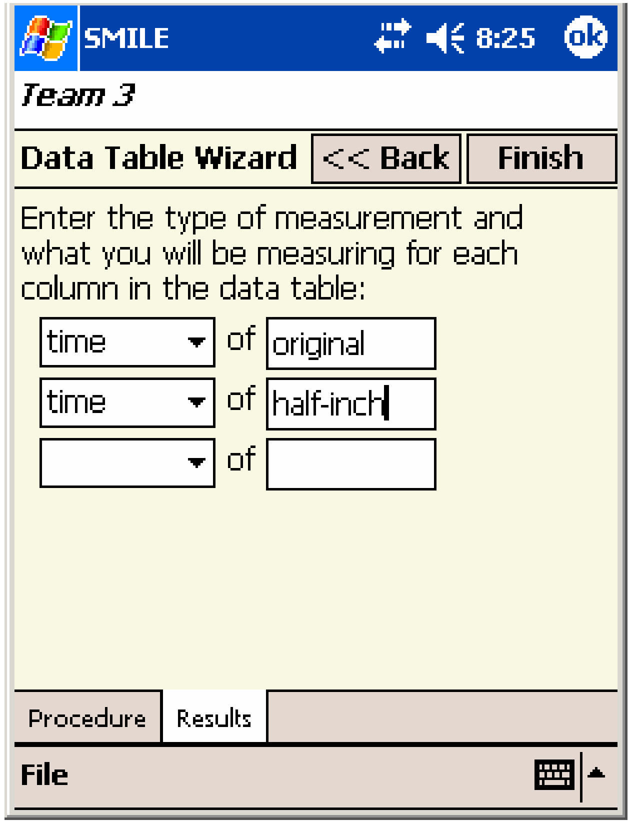
- Students plan and reflect around the computer -- 2 or 3 at a time. They print out what they need for further work and move to the floor or lab or construction table to continue, coming back to the computer and typing in test or experiment results they collect.
- But with a desktop computer, they can't easily integrate design of experiments and data collection and interpretation.
- But these days it makes sense to think about the role pda's can play. We're in the process of thinking through and adding integrated pda facilities for the kinds of things the kids do "on the floor" or "at the lab table"

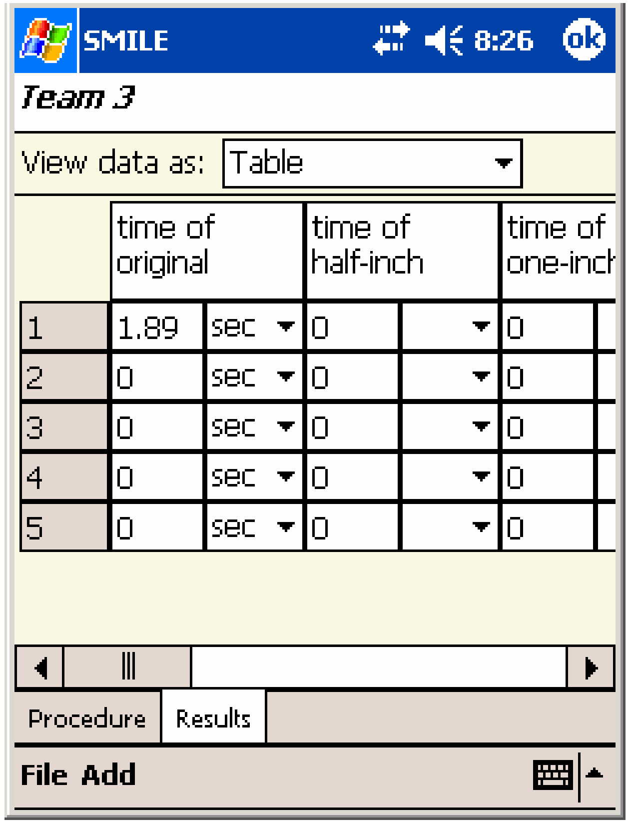
Palm Accessory to SMILE
a procedure/data table wizard



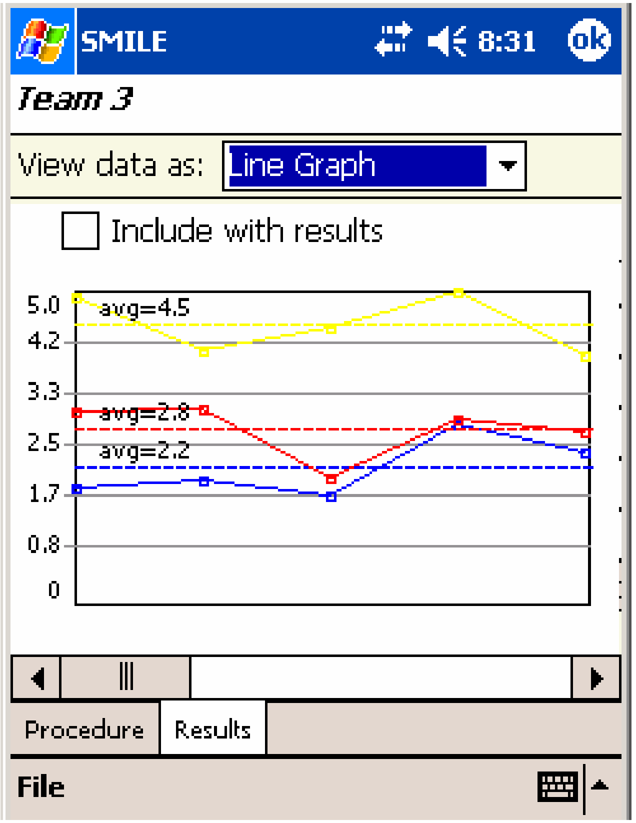


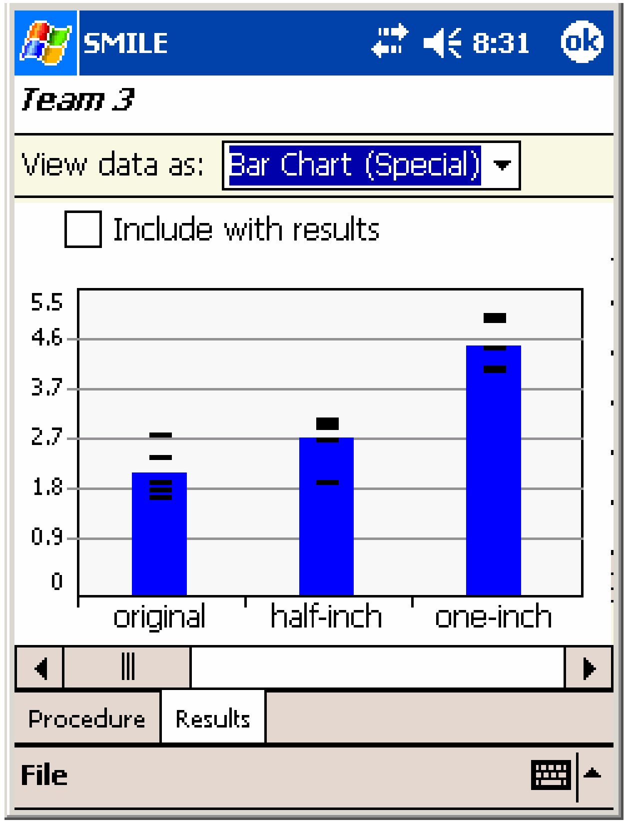
Setting up a table (cont.)





Visualizing data

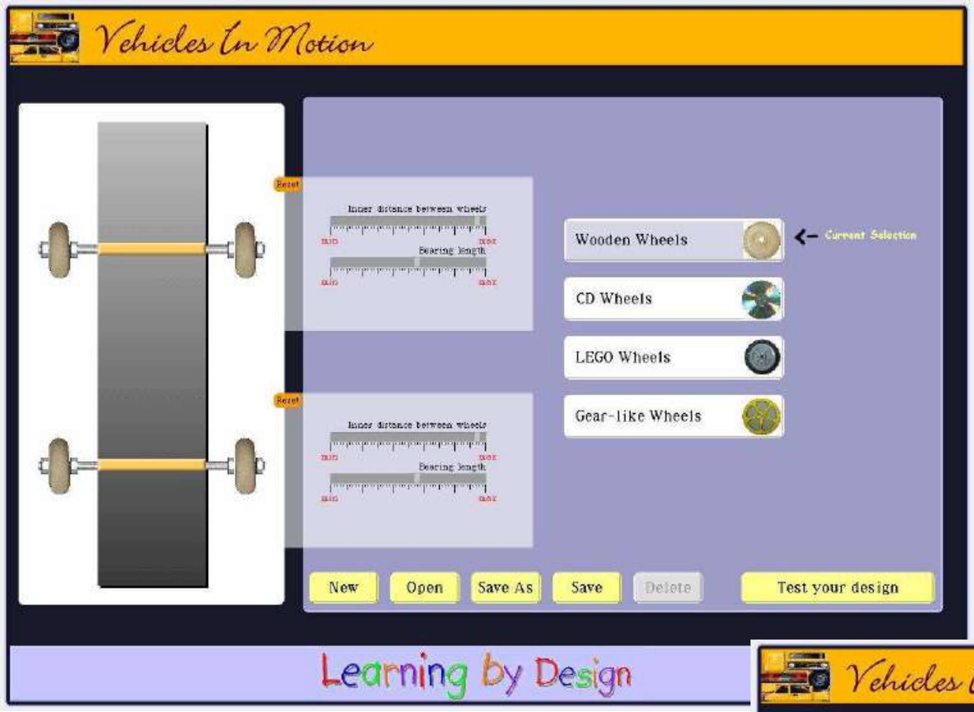


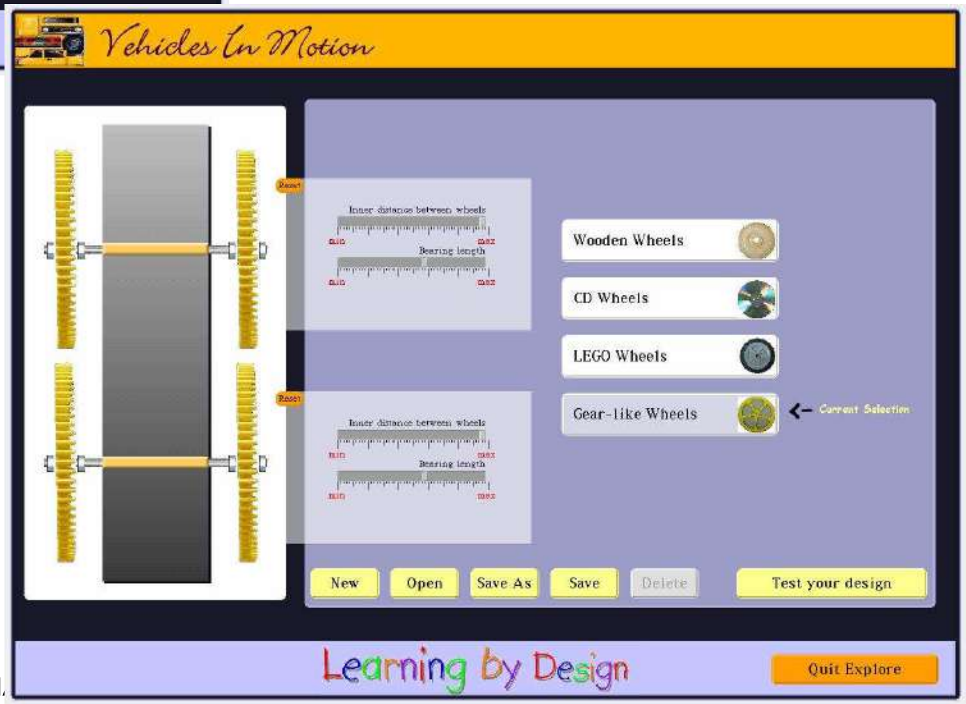


Vehicles in Motion modeling/simulation software

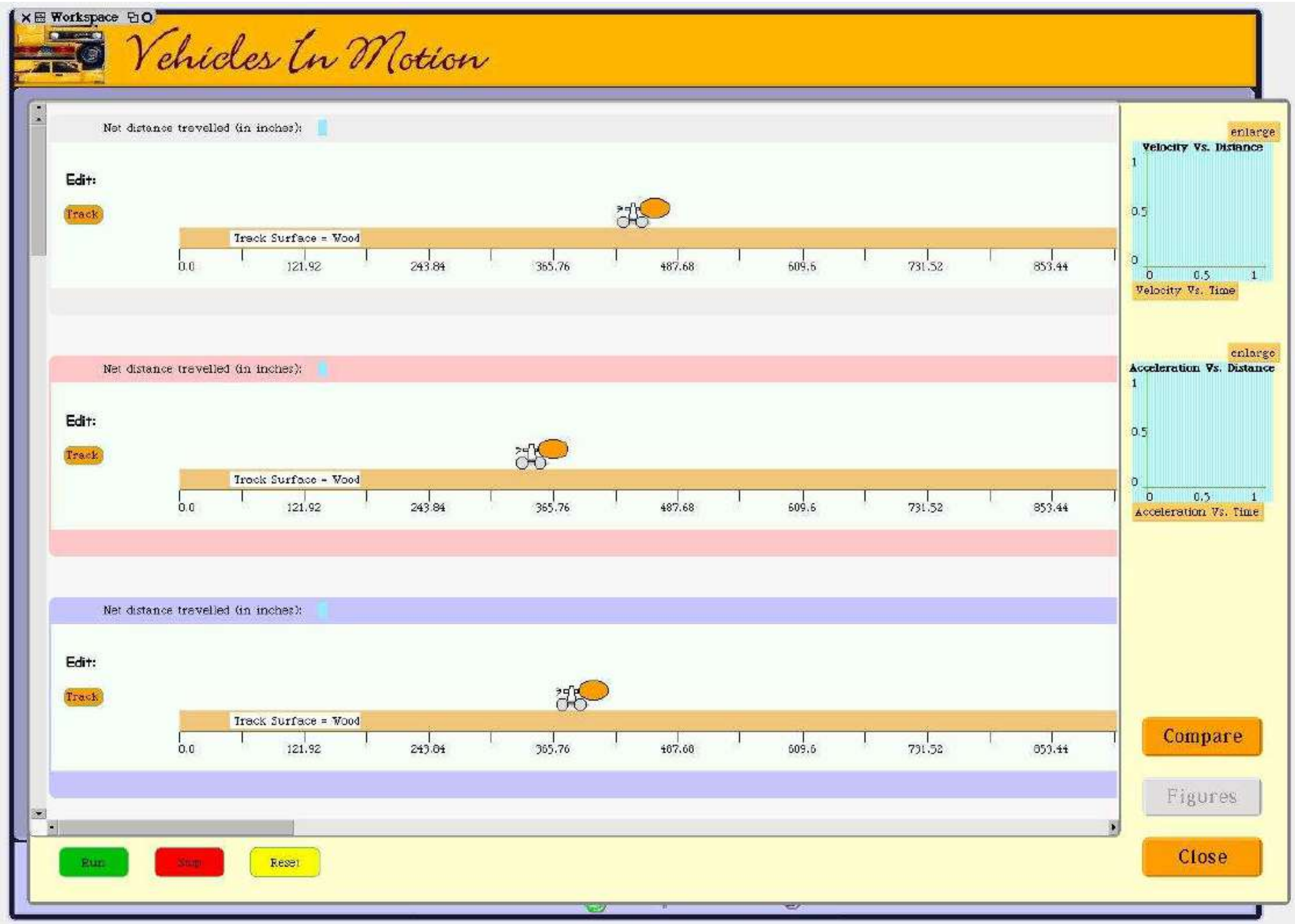
- Designed to augment the designing and building kids do with physical manipulatives
  - Adds exactness to data collection
  - Provides extended opportunities for exploring effects of design changes
  - Helps with predicting and explaining behavior scientifically

Virtual models match real-world models


Vehicles In Motion
Inner distance between wheels
Bearing length
Wooden Wheels
Current Selection
CD Wheels
LEGO Wheels
Gear-like Wheels
New
Open
Save As
Save
Delete
Test your design
Learning by Design


Vehicles In Motion
Inner distance between wheels
Bearing length
Wooden Wheels
CD Wheels
LEGO Wheels
Gear-like Wheels
Current Selection
New
Open
Save As
Save
Delete
Test your design
Learning by Design
Quit Explore

They can compare behavior of different designs



In experiment mode, the system asks for predictions about how cars will perform

Introducing PBIS

- Project-Based Inquiry Science

LBD had inadequate coverage

- 1 year of science; some physical science and some earth science; no publisher would publish LBD
- Northwestern and Michigan were working on another similar approach -- focusing on learning science in urban schools
- We created PBIS (Project-Based Inquiry Science)
  - a full 3-year middle school curriculum
  - 4 to 5 units for each discipline -- physical, earth, life sciences
  - integrates and refines lessons learned from development of LBD (GA Tech) and Project-Based Science (Northwestern and Michigan),
  - integrates adaptations of units developed at all three places plus other units
  - takes units from "locally-usable" to "(inter) nationally-usable" and from being single units to being integral to a curriculum

Project-Based Inquiry Science (PBIS)

- Published by It's About Time, Inc.
- Each unit has learners address a potentially-engaging big question or achieve a big challenge
  - How can you keep your friends from getting sick?
  - Design a vehicle that can travel straight and far and carry a load.
  - Help a set of scientists access their supplies.
  - How should a town regulate a new industry?
  - Design a new breed of rice that has more nutritional content and doesn't need as much water.
  - Why so many volcanoes and earthquakes?
- As in LBD, everything learners do in a unit helps them work towards answering the question or achieving the challenge.
- Addressing a unit's challenge requires learning targeted science, scientific reasoning collaboration, communication, design and planning, … -- the things we want them to learn
- As in LBD, the first unit of each year is a Launcher -- helps kids know how to participate as scientists and develop a culture of rigorous science talk and collaborative learning

Conventions -- As in LBD

- Project Board
- Communicates
  - Gallery Walk/Solution Briefing -- scaffolds scientific explanation
  - Pin-Up Session/Plan Briefing -- scaffolds justification with evidence
  - Poster Session/Investigation Expo -- scaffolds investigation, data interpretation, learning about trustworthiness of data
- Embedded Formative Assessments
  - Rules of Thumb/Create your Explanation -- scaffolds data interpretation and explanation creation
  - Stop and Think -- scaffolds identifying key points
  - Reflect -- scaffolds deriving implications
- Launcher Units introduce community practices and norms
- Each convention has a purpose, sequencing, place in the sequencing, and ways of doing

The PBIS Project Board

What is the challenge?

What do we think we know?	What do we need to investigate?	What are we learning?	What is our evidence?	How does it apply to the challenge?

Discussion around the Project Board moves the unit forward and maintains context and momentum.