Learning Scientists Changing the World: Challenges and Opportunities

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Notice: Not the National Science Foundation

Some History

- Late 1989: Beginning my work founding *The Journal of the Learning Sciences*
- Early 1991: First issue of *JLS*; I wrote an editor's column introducing the journal
  - I hoped we would be influencing education and using the journal as a vehicle for discussions with education professionals (teachers and administrators)
- Early- to mid-1990s: *JLS* becomes an education journal
- Early 2000s: ISLS is founded

- The goals have been to both learn about learning in real-world settings and have an effect on education
  - Along with a strong belief that creative use of technology can provide some of the answer

So where are we today?

- We know a lot about learning, promoting learning, and promoting learning with technology.
- We know a lot of ways technology can provide opportunities for learning that are not available otherwise.
- We've designed some appealing software based on what is known about how people learn.
- We've published curricula and curriculum units and resources for helping teachers promote engagement and learning better in classrooms.
- We are continuing on that trajectory, and the software and curriculum units are getting more and more exciting.

- There are things we don't know, but still, there is a lot we know that could have an influence.

But …

- Overall, we've made very little progress taking our research into practice (we have people on all the national and international committees, we have little roll-outs, hundreds of thousands of people have used Scratch, but we haven't fundamentally changed anything)
- We've made little progress rolling out products and less progress evaluating to show what works
- We have so much to offer, but …..

HOW?

This talk

- The future of learning environments – what we want to see going on in learning environments
  - Based on what we know about promoting learning in a way that engages everyone
- The future of learning technologies – bringing together where policy is going with what's possible and what we want to see
  - Based on what we know, what we've created and have data about, and what today's technologies afford
- What we need to do as a community to have influence
  - Not politically or policy-wise; rather, our MO as a research and development community

- Remember: This is Kolodner talking, not NSF!!

Imagine: The Future of Learning Environments

- As long as people need to make a living, school is not going away.
- But
  - School is not the only place children can learn;
  - Children, teens, and young adults are not the only people who have learning needs
  - Authority figures don't have a monopoly on ability to facilitate and promote learning
- Warning: The computer by itself will not address all of society's education needs. Dede: It's really easy for anytime, anywhere to become notime, nowhere.

Imagine: School is not the only place for learning ...

- The class visits the science center or aquarium together to collect data for addressing an ecosystem problem
- Parents and kids go together to a maker space and build a robot that changes direction when light is shined at it
- Parent and kids repair a car or tractor together.
- Parent and kids perfect recipes together.
- Kids play games together.
- Communities of gamers or hobbyists achieve goals together.
- ...

Imagine: It's not only kids who need to learn …

- New parents learning parenting skills (or how to help their kids learn)
- A new employee needs to learn the practices of a shop
- Families learning together about energy and energy use and making good decisions about energy use, buying a car, …
- Middle school girls learning to cook together and in the process learning about heat transfer, chemical reactions, experiment design, …
- Fishermen on the coast wonder how to manage their fleet given the changing climate conditions
- Vintners managing the grape growing in the different parts of their fields

Imagine: Authority figures have no monopoly on facilitating learning …

- A college student or young professional is working with the middle school girls and learning with them …
- Older kids helping younger kids program apps
- Worlds of Warcraft players of all ages giving each other advice about strategy and play
- Samba School in Brazil, Mummers clubs in Philadelphia, a church putting on a play as a congregation, musicians in New Orleans, …

None of that took very much imagination, so what's new?

- The 21st Century
  - Everybody needs to learns the things needed to participate fully in the workforce and citizenry (because we're past factory jobs for most)
  - Everyone needs a spirit of learning (because they say from now on nobody will have just one job or career in a lifetime; because available tools change fast, requiring everyone to develop new skills and capabilities)
  - Everyone needs to appreciate the roles of scientists and other experts (because the issues we need to address as a society are so complex, and therefore those we put into office need to …)
  - Economic challenges and growing disparities between the haves and the have nots are feeding vicious cycles (and education may be a way to move past those cycles)
- School, as we know it or otherwise, can't do it all
- But, in any event, what school provides will need to be transformed to achieve 21st century competence
  - Goals of promoting learning have to be more consistently achieved.

We know a lot about achieving these objectives (and I want to remind you what we know; my favorites)

- Learning deeply, a process of mental model building, takes sustained and long-term effort and often requires a lot of help.

- Promoting and sustaining active engagement is somewhere between 50% and 80% of promoting learning. (I made that up, but …)

- Everyone's interests aren't the same and everyone's Zone of Proximal Development isn't the same, so a one-size-fits-all approach to promoting learning simply will not work.
  - Applies to teachers/mentors as well as learners.

Learning deeply takes sustained and long-term effort and requires help

- Learning is a process of <u>iteratively</u> constructing, revising, and connecting together mental models -- models of what we know and models of how to do things – Piaget, …

- Becoming fluid at reasoning skills is an <u>iterative</u> process of composing and debugging sequences of "how-to's" -- Schank & Abelson; Anderson; Newell, Rosenbloom & Laird

- We can only learn on the edges of what we already know (Zone of Proximal Development -- Vygotsky)

- We know we need to learn something when a mental model or how-to sequence doesn't do the work we want it to do -- either we can't do something we want to do or something turns out differently than we expected or something happens that we weren't expecting and we can't explain -- Schank & Abelson, Anderson, …

- A great deal of reflection and interpretation are needed to recognize the need to learn and to troubleshoot and revise one's mental models -- Bransford, Collins, Schank, …

Helping Learners Build Mental Models

- Framing first, details later -- Collins
  - Help learners 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
  - Allow learners to notice, allow learners to identify what they do and don't understand. Promote identifying holes in one's mental models and generating questions
- Tell only when learners are ready to have answers, and give learners a role in telling their peers.
- Help learners care enough (so they have learning goals) to put in the mental energy to construct and revise mental models.
- Help learners connect their mental models by helping them recognize and revisit what they already know and the implications of that on what they are learning (knowledge integration; Linn)

Intrinsic Motivation Promotes Sustained Active Engagement (and remember, promoting sustained engagement is 50 to 80% of the answer)

- Personal and epistemological connections promote engagement (and learning) (Papert, Resnick, …)
  - Learners connect when they have prior knowledge to help them connect.
  - Learning connect when they are interested.
  - Learners connect what they are learning to the real world when they are helped to make that connection.
  - With a goal in mind, learners will themselves become curious and want to learn.
- "Communities of practice" work together to help each other achieve goals (Lave and Wenger)
  - Encouraging community (affinity groups, interest groups, communities of practice) encourages engagement.
  - Community can be created in formal and informal learning environments, with engineered early activities to promote shared values and ways of doing; continued work together to sustain the community (Kolodner)
  - Community engagement gives learners opportunities to imagine what they might be, and mentors can help learners align themselves to their imaginations.

Sustaining Engagement (cont.)

- "Thick authenticity" for maintaining integrity (Shaffer and Resnick)
  - Keep it real to keep people engaged – "thickly authentic" in the mind of the learners
  - personal, disciplinary, real-world, assessment authenticity
  - Solving problems relevant to the world learners live in, having available the same kinds of tools and resources professionals would have
  - A big question or challenge promotes personal connection (Krajcik, Edelson, Reiser, Kolodner)
  - Assessment is embedded, relevant to learners' goals, and meaningful to learners
- Turning over agency to learners allows learners to decide for themselves to participate (Holland)
  - Encouraging agency encourages engagement; encouraging agency encourages disposition.
  - And we know some things about doing this in a way that promotes learning and allows forward movement of the learning group as a whole
  - Knowledge building with a community results in collective cognitive responsibility, mental model building, and knowledge integration among community members (Scardamalia, Bereiter, Linn)
- Providing scaffolding that promotes success and self-assessment keeps it challenging but not not out of reach.
  - An art, but …

Learning Environments of the Future: What we know they need to be

- *Lessons* will be de-emphasized
- *Challenges* will be emphasized
  - Challenges are not exactly the same as projects
  - Projects are about doing something; challenges are about achieving something
- *Activities* will be in the context of challenges, and *lessons* in the context of *activities*
- *Lectures* will be for purposes identified by learners, and they will often be short and impromptu, recorded and available as needed (to be watched together as a group and stopped and started as needed or watched and then discussed), or interactive
- *Reading*, like lectures, will be for purposes identified by learners to answer questions they have raised or to provide details on what they have already experienced or conceptualized

What will classrooms look like?

- Classrooms will be places for addressing challenges *together*
  - solving problems and/or achieving design challenges and all the reasoning and discussion needed for learning from those experiences
  - Challenges interesting to the learners – perhaps local, perhaps not everyone will work on the same challenges, perhaps groups working together will not be co-located
  - Activities will be varied; lectures will be uncommon; reading and lectures will be accompanied by scaffolding; peers will share responsibilities for promoting learning with the teacher and technology
- Learning will be purposeful
  - A focus on learning what's important – skills and practices for living a life, for stewarding a planet, for health and well-being, for someday joining a workforce and actively participating in civic life
  - Reading, writing, mathematizing, content important to those goals
  - Opportunities for promoting learning will be grabbed from the experiences learners are having, and what we know about mental model building will be used to help learners learn from those experiences.
  - Learning of content and reasoning will be integrated by having learners learn them in a context of real and necessary use.
- Assessment will be purposeful
  - Not simply for accountability but for purposes of scaffolding and promoting self-recognition and learning
  - But accountability will be important (the system is going in that direction)
- Learning technologies will be used for a whole variety of purposes and integrated into activities in purposeful ways.

Some of my favorite examples (from my own work)

- In PBIS, over a 10-week period, middle schoolers learn chemistry in the context of working toward making suggestions to improve the air quality of their community. Along the way, they
    - walk around their neighborhood to find sources of pollution, and look on the web to find sources of pollution.
    - build models (physical) to understand better what air is and what it means for air to be polluted.
    - read case studies of air pollution in Los Angeles and in the Adirondacks in New York State
    - use a physical modeling kit to build molecules, to understand bonding, to model chemical reactions, and to concretely conceptualize the differences between stable and unstable molecules
    - build a physical model of convection, and then view video of several more sophisticated models of convection and of the effects on convection of land forms and how that keeps pollutants from dispersing
    - read about catalytic converters, power plants, and the many different ways their emissions can be lessened (some ways work physically and some by chemical reaction), an use what they are learning about chemical reactions to explain how each works and to predict the effects of each
    - Develop and refine explanations of where pollution comes from and how it can be mitigated
    - examine data from before and after the Clean Air Act was passed.
    - apply their explanations to what they know about community pollution sources and make suggestions
    - Why would they be interested? They're told a fable early on about effects of bad air, and it gets them thinking …

Another …

- After school, a group of middle schoolers learns to be scientists in the context of cooking – creating and perfecting recipes (with my students, Tammy Clegg and Christina Gardner; Kitchen Science Investigators)
    - They plan and run cooking experiments to learn about the effects of ingredients
    - They keep track of and analyze data together, data to answer questions they need answers to to perfect their recipes
    - They keep track of the paths to "perfect" recipes so they can retell their stories.
    - They publish tips and tricks that include explanations that support their suggestions
    - They publish recipes and, *a la* some cooking magazines, the stories behind their recipes
    - They use technology for planning experiments and other investigations, for keeping track of their ideas and evolving recipes, for managing data and keeping and accessing data tables, for looking up what they need to know, for publishing their tips, tricks, and recipes
    - One becomes a measurement expert and takes her expertise back to science class; another has an aha about science – it isn't just about explaining, it's also about investigating to find explanations; another makes a whole new group of friends who she enjoys talking science to; …
    - Why would they be interested? They want to cook for their friends and family; they want the pats on the back for their food being interesting and good. Their imaginations are enticed early on with questions written in to a food column asking how-to's

And another …

- In PBIS, over an 8-week period, middle schoolers consider how to create a new breed of rice that both needs less water to grow and is high in nutrients. Along the way, they
  - Simulate Mendel's experiments
  - Physically model effects of gene combination (building little beings from marshmallows and pipe cleaners)
  - Simulate ecosystems and the effects of drought, too much rain, extra predators, and so forth on population growth
  - Argue the pros and cons of genetic engineering
  - Use Punnet squares over and over to make genetic predictions
  - Why would they be interested? Because early on the unit tells them about life in the Phillipines, where there is/was a problem with rice growing and proper nutrition
  - …

In all, students …

- Draw out lessons from what they are doing as they prepare to share their procedures, results, and insights with their peers
- Self-assess in response to questions and comments from peers
- Answer embedded reflection questions that help them (and the teacher/facilitators) know what they understand and don't, draw connections, and make predictions
- Help each other understand, make predictions, explain
- Investigate to answer questions they, as a class/group, have derived
- Compare and contrast results of experiments and other investigations across groups
- Break a big challenge down into pieces, address each using what they are learning, and pull the whole together
- Reflect continuously along the way on what they are doing, how to do those things effectively, what they are learning, evidence that supports what they are learning, how they are learning those things, …
- Address challenges together, investigate with a purpose in mind, practice with a purpose in mind, experience and draw lessons from problem solving experiences, experience the value of content they are learning and of deeply learning that content, experience the value of working together, …
- Use learning technologies with purpose in mind (though not with every purpose technology could be used for)

Learning Technologies will serve many purposes in future learning environments

- Modeling to promote learning about systems and the ways their pieces are integrated and affect each other
- Simulation to understand what happens when
- Communication for community finding and community interactions
- Communication for connecting experts with learners and learning environments
- Video for self-assessment, video for teacher learning, …
- Visual interfaces for access to data (sometimes the big data of scientists, social scientists, and engineers)
- Analysis and visualization tools for interpretation of data
- Wikis, blogs, and so forth for sharing
- Embedded assessment for both educational purposes and accountability
- …

- We don't lack imagination about the roles technology might play

But in the future …

- No technological tool or function will stand alone
- Integration will be key
  - Of functions, e.g,. data collection, access, analysis, visualization
  - Across disciplines
  - Across time
  - Of doing and assessment
  - With activities of engaging in challenges, and with challenges themselves
  - Across activities in and out of school
  - Across teacher and student learning
- Apps will be have to be interoperable with other apps
- Platforms that integrate will be the rule

- We have that now for office work, and some professions have it; such integration will be essential in learning technologies if they are to be broadly adopted

First attempts: A few examples from the first year of the Cyberlearning program at NSF

- GeoGames – Ohio State, Ola Ahlqvist et al.
  - undergraduates learning to reason about public policy play GeoGames to learn geospatial thinking and the skills and ability to use big data organized geographically to solve complex problems
  - GeoGames are problem-solving scenarios across agriculture, transportation, relief, emergency aid, and other policy areas that require reasoning about effects of nature and policy on geographically contiguous spaces
  - On-line maps give access to GIS, remote sensing, socio-economic, agricultural, and other data
  - Learners play roles in different geographic areas and interact to explore how what's done and what happens in one area affects other areas
  - Early games encompass simpler connections; roles become more sophisticated, need to take more contiguous areas into account or to examine each area in smaller chunks in later games
  - Playing the games promotes familiarity with issues, question asking, experience with problem solving, policy making, and effects of policy
  - Class time is for discussion, reflection, identifying what needs to be learned, and the occasional lecture
  - Note the integration of formal and informal activities, learning in the context of challenges, progression of challenges, integration of doing and reflecting, engagement through community and thick authenticity
  - Challenges are in the design of an interface, the integration of activities on and off line, and the promotion of geospatial thinking and complex problem solving
  - Integration is of technology use and in-class/with teacher activities; use of geospatial representations for data access over time and for several purposes

English-Language Learning

- Contextualized English Language Learning, Mendez et al., Springfield Community College, Massachusetts, USA
  - Refugees and immigrants need to learn English to matriculate to college, but they are often working several jobs, taking care of a family, and going to school at the same time; they don't have time to be around English language speakers who they could practice their English with
  - Students learning English can interact on their own time in a 3D virtual campus community
  - The courses focus on the English students need to get around in the community, to get around on campus, and to begin to take courses
  - English-speaking assignments complement the English speaking and instruction in class.
  - Making the virtual campus work has scaffolding challenges and social challenges – scaffolding to allow learners not to be embarrassed by their accents and poor grammar and vocabulary, and incentives for the English-language population in the campus community to participate online
  - Integration is of in-class and out-of-class activities; community involvement in promoting learning

Family Learning

- Michael Horn, Reed Stevens, Northwestern U
- Families interact around an instrumented thermostat and a platform with simulation, resource access, and family energy use data to learn about energy and resource use
- The need to both regulate temperature in the house and keep expenses down promotes family discussion; the challenge is to find what resources, simulations, and data visualizations will keep the family engaged over time in discussing and learning more about the science of energy and issues of energy resources
- Integration into the life of the family is the big challenge; integration needs to happen in a way that integrates promoting question asking, promoting exploration and investigation to answer those questions, and promoting self-assessment that allows family members to know what they understand and what they need to understand better

Student Scientist Platforms

- Martin and Christy, U Mass Lowell

- Dorsey, Wilensky, Finzer, Concord Consortium, Northwestern U, Key Curriculum Press

- Both focus on learning how to support authentic scientific inquiry in a way that promotes deep scientific inquiry, conveys an accurate understanding of the practices of scientists, and helps students become data scientists

- Both are integration initiatives, focused on integrating sets of learner-appropriate scientific tools for student scientists and on integrating use of such platforms of tools into the everyday activities of science classrooms

- Dorsey et al. focus on pedagogical practices for integrating the use of such a platform into classroom activities without overwhelming students or teachers with the rich set of possibilities and on technological needs in integrating multiple tools

- Martin et al. focus on integrating data collection devices into such a setup and creating a sense of community across classrooms that will help students see themselves as part of a community of student scientists and teachers as part of a community of learners of how to facilitate such learning

Getting to full integration will take time

- None of the examples I discussed is as completely integrated as I think technology will need to be in the future for adoption

- But each is a start

- Notice that none assume school as it is today

- And I think that soon no technologies will be broadly adopted in schools unless they incorporate assessment possibilities – some combination of feedback to learners, feedback to teachers, and accountability information

How can we have influence?

- Practice what we preach.
  - If we believe all of these things about promoting learning, let's make sure our own classes and, for education school people, the curricula of those who will be teachers, are exemplars of good practice.
  - Make sure the products we develop and the conditions for investigations we choose match what we know.
    - Deep learning requires sustained long-term engagement
- Build on each other's work, and add to our intellectual agenda a focus on integration.
  - It can't all be about each of our small projects. It can't all be about our own favorite ideas. Our ideas taken together can accomplish a lot more than any of the ideas that come from one person or place or lab.
  - Our egos need to be set aside for the greater good.

Having influence (cont.)

- Add moving from research to practice to our community agenda and to the agendas of more of our community members
  - This means working with interpreters and integrators – those who can take the best of our ideas and the products of our research and mold them into integrated platforms and packages
    - PBIS (a full 3 year curriculum) has foundations in both Learning by Design and Project-Based Science; the ideas from both were needed to succeed; the products of research (curriculum units) were needed to succeed; the whole is bigger than the sum of its parts, and no part integrated into the whole escaped significant refinement and sometimes total redefinition
  - We need to welcome such integration and work with those who are willing to integrate to make sure the integrity of the original ideas remains as the whole is created; an integrator will know how to make the most of technology, integrate in new interface technologies, and work towards making it work for teachers
  - We don't all have to take our research to practice; we do all have to be willing to hand over our products and remain available to help
  - We need to distinguish between the principles in the products of our research and the products themselves and be humble about what we know and don't know about what makes them work
  - We need to educate some of our students to be interpreters and integrators, or we have to help educate folks out there who want to do that work

Having influence (cont.)

- With respect to taking curriculum into practice,
  - Think variety.
  - Think integrated over time – learning trajectories across grades
  - Think integration with technology but not technology taking the place of doing in the physical world.
  - Think agency, sustained engagement, thick authenticity; don't give in to old-school-like!!!
    - Standards tell what to aim for; they don't tell how to get there.
  - Remember that learning requires sustained engagement over significant time periods; don't sell out on this!!!
  - Think about what's most important with respect to learning. Don't compromise on those things!!!

Having influence (cont.)

- With respect to taking technology into practice,
  - To promote good classroom use, teachers need to know how to use it; it needs to be integrated into good, published curriculum and curriculum units (challenges)
  - Assessment must be integrated, with feedback to learners and teachers, and with accommodations for accountability
  - Learning often happens in the interactions between community members between uses of technology; make that part of the design of the technology and its packaging for use
  - Think mobile; not everything has to go on a tablet, but don't forget their affordances.
  - Think integrated platforms.

Having influence (cont.)

- Spend more time and effort evaluating the products of integration and do that evaluation in ways that show under what circumstances they are effective
  - Large controlled random trials only after we know why and under what circumstances the technology works effectively.
  - Don't sabotage those trials; make sure they are set up for success – e.g., with appropriate teacher prof dev
  - Smaller trials first to show why and under what circumstances an innovation works.

Having Influence (cont.)

- There is a lot in taking research to practice that is hard; what we can do is help the public and the policy makers have imagination.
    - We need to get products out there that show what can work.
    - We need to get them out there in ways that make it easy for teachers to see how to use them.
    - We need to model for future teachers what's possible.
    - We need to show the circumstances under which our products and approaches work and what makes a difference in their context of use.

Having Influence (finally)

- Work on what's important
  - Begin with a challenge in mind
  - One with national or international importance
  - Focus on the transformational part of it
  - Make sure you are forward-looking; not everything we do needs to be about school, and certainly no buy-in to school as it is today
  - Your research outside of school may make it into school someday; there's no need to start in school to learn how to promote transformational goals
  - If you're not drawing from at least 3 literatures, what you're doing is not important enough
  - If you're not drawing from what is known outside of your lab, it's not important enough
  - Really transformational work requires careful exploration before controlled experiments or even quasi-experiments; don't jump to comparisons too soon; focus on understanding affordances and challenges to effective use first, but don't stop there; keep going and bring your innovations to fruition

Thank you!

An Example: GenScope

- As a "complement to text-based instruction," it provided 6 integrated layers for exploration of genetics and inheritance (DNA, chromosome, cell, organism, population, and pedegree) that allowed students to "actually observe and manipulate processes at one biological level that affect life at another."
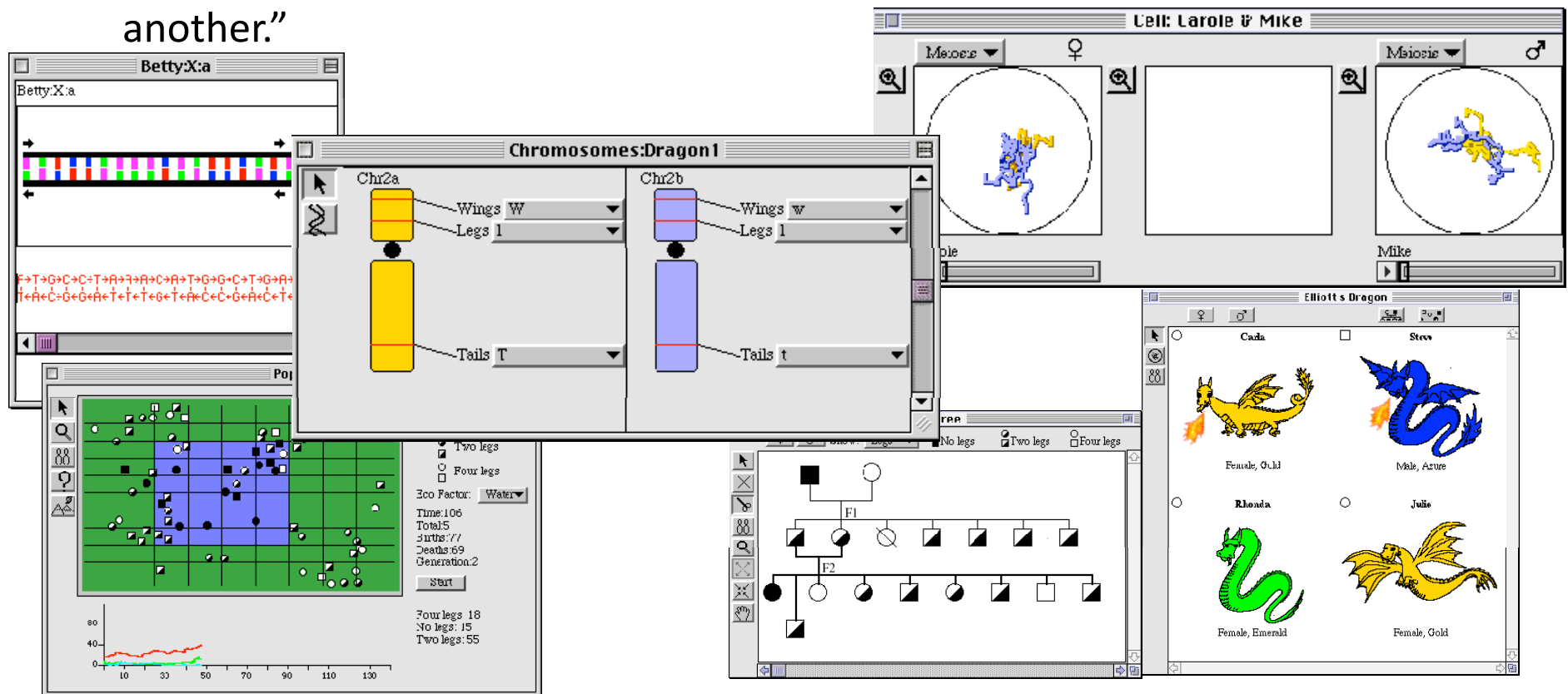
Genscope got a lot right

- It began as a resource in support of exploration to learn genetics and inheritance
- It could be integrated in lots of different ways into biology courses.
- BUT … some teachers used it well, some didn't, and most of the time, students came away knowing about dragons but not genetics and inheritance
- Added to this along the way were
  - lesson plans for using GenScope to help high-schoolers and middle-schoolers understand genetics
  - An introduction that led users through what Genscope could do
  - Assessments teachers might use
  - The focus was on using GenScope well, and lesson plans and introduction were designed to do this in a way that promoted learning genetics and not just about dragons
- BUT … My claim (not NSF's): The life force of GenScope was sucked out by those additions – they were written to promote learning "the facts" that had to be learned, giving lesson plans to teachers that focused them away from having learners explore
- That it stood alone was a major problem; teachers are not educated to write curriculum, and they can't figure out how to use technology by themselves