The Political Ecology of Design and Technology Education: Toward Sustainable Practice

ABSTRACT:

Forget the methods until you get the atmosphere right, then choose a method that fits that.

(Jones quoted in Mitchell, 1993, p. 57)

Among the most deeply entrenched models in technology education is the design, problem solving, or technological 'method'. While the shift of attention from skills to process has helped to change practice, these models offer a value-free, instrumental view of knowledge. The models are supposedly applicable across culture, geography, and time. Certainly, there are good reasons to reconsider these dominant metaphors. The design, problem solving, and technological method simply amount to bad pedagogy, psychology, and sociology. As researchers in education, design, cultural psychology, and sociology have shown, design and technological methods are neither conducive to student work nor ontologically sound. These methods are rooted in a psychology of the private, Euro-centric intellect rather than in the everyday, sociopolitical mediation of culture and nature. We argue here that these methods are also inadequate for practice in the face of cultural change and environmental degradation at dawn of a new millennium. Through a political ecology of design and technology, argue for the reconceptualization of current methods. This argument compliments an earlier article in which we argued to reconsider methods from a *problem posing* perspective (Lewis, Petrina & Hill, 1998).

The trouble with our conventional models of design is that they're woefully inadequate in accounting for much of culture's and nature's places in the process. Conventional models— 'Identify a Problem', 'Generate Solutions', 'Choose, Construct, and Test the Best Solution', and 'Implement and Evaluate the Design'— fail to account for life cycles in a political ecology of design and technology. These models are technocentric and overly simplified representations of an

This article is about rethinking our relations with the environment as we rethink educational and design processes. It is about moving from a logic of design method toward an engagement with life cycles and ecology. As we report on our experiences in teacher education, we will provide an outline and strategy for reconceptualizing bridge building activities for young people.

Bridging Life Cycles

The trouble with our conventional models of design is that they're woefully inadequate in accounting for nature's place in the process. Conventional models— "Identify a Problem," "Generate Solutions," "Choose and Test the Best Solution," and "Implement the Design"— fail to account for life cycles. These models fail to lead us to ask: What happened before? What happens next? Where did the resources come from? Where does the waste go? Who extracted and developed the resources? Who will maintain the product? What recycled waste went into materials? Will the product be recycled? What will the product's relation to nature be? The trouble with conventional models of design is that they're rooted in present economics, *not* past and future ecology.

The challenge for designers and teachers of design is to bridge material and product life cycles with natural life cycles. Products, whether they be barges, bridges, or burgers have a *resource stream* and a *wake*—they're related to nature in some small or large way. Some ecologists prefer to think of resource stream as "material life cycle" and wake as "product life cycle." Both of these cycles interrelate with the life cycles of living organisms and micro-organisms. In other words, our social ecologies interrelate with our natural ecologies. When we design and teach design however, we invariably forget about streams and wakes. We forget what a bridge is for.

In the July of 1997, a group of five pre-service technology teachers at the University of British Columbia (UBC) set out to change the *status quo*. In a course called the "Pedagogy of Engineering Design," co taught by engineers (Dr. Donald McAdam, Aaron Bohnen) and teacher

educators (Dr. Ann Marie Hill and Dr. Stephen Petrina), the students literally and figuratively reconceptualized the bridge project. In so doing, they had to unthink design and rethink life cycle.

Over the past two years, UBC's Technology Studies program and the Mechanical Engineering Department collaborated to provide pre-service teachers with a course in engineering design. The course is a popular elective and is project oriented. In a three-week term, the students complete one statics project and one dynamics project. The statics challenge is to *design the most efficient structure for bearing the maximum load.* Students work in teams to design, model, and test a structure such as a bridge or water tower under certain constraints. Lessons are given on the distribution of forces across tension and compression members of structures, the structural action and behavior of different materials under these forces, and on structural design. In the process of designing the students are required to maintain portfolios. The end of the project involves the conventional test of load bearing capacity—bridges or towers are placed on the table of a giant compression testing machine and loads are gradually increased until the structure fails. Failures or fractures are analyzed and knowledge gained is brought to bear on the structural designs. This project provides a nice orientation to structures, but it is nothing new.

Two groups of students—we'll call them design outlaws— petitioned to take an unorthodox approach to the statics project. They asked if they could design to bridge their structural engineering knowledge with ecology; they weren't interested in smashing bridges. Then they asked if they could combine their groups of two and three into one group of five, as competition wasn't their bag either. After further explanation and to avoid forced conformity, the instructors encouraged the "group" to develop their ideas. We really had no idea what would develop, but had confidence in the talents of the students. The instructors only caveat was that they carefully document their reconceptualization of the bridge project. This report is the fruit of the hard labor of the design outlaws.

The Mosquito Creek Footbridge

Since the earliest days of the "North Shore" of Vancouver, BC, hiking the local mountains has been a popular pastime for area residents and tourists. Over the years a network of trails has evolved providing access for the fit, and not so fit, to experience the wonders of the natural forest environment. The natural terrain of these mountain slops can be extremely rugged. Episodes of high rainfall frequently occur in the west coast temperate rain forest. Deep ravines and steep canyon walls are testimony to the rain-swollen creeks that often rush down these mountain slopes, as they seek the equilibrium of the sea below. As the mountain trails traverse these slopes, they cross the creeks. Historically it has been a challenge for trail builders to design and construct these trail bridges.

The Mosquito Creek footbridge is an example of one such crossing. The Baden-Powell Trail which crosses on the bridge is a vital local trail. It traverses the North Shore mountains from Horseshoe Bay in the west to Deep Cove in the east, as well as providing access to other high mountain ridge trails. The Mosquito Creek crossing is the first wilderness point on the trail leading up to a spectacular waterfall and some of the larger Douglas Fir trees found in BC. It is a point where hikers leave the city behind to immerse themselves in the natural beauty of the forest. It is not known who built the original crossing, but it just "disappeared" during a rain storm over the winter of 1980. A local hiking club designed and built a log-beam crossing at the site in 1981. That structure was demolished in 1996 after an inspection revealed that the main spanning log beams had already rotted to the point of being unsafe. The engineer who inspected the bridge felt that faulty detailing along with some poor building technique had led to this bridge's demise long before what one might normally expect. A new bridge for the 75 ft (23 meter) span was recently installed by the District of North Vancouver.

Over the years, development on the North Shore has continued up the sides of the mountains. Where once not long ago the Mosquito Creek footbridge existed somewhere remote from housing, it now resides only about 1,000 feet beyond the limits of residential development. Present zoning does not allow for further residential development above the existing boundary.

The Mosquito Creek footbridge site is expected to exist in the future in its present semi-wilderness state.

Whereas historically the footbridge was used only by hikers and the occasional angler, today the area is experiencing increasing pressure from other users. In particular, mountain bikers are finding the mountain trails more and more attractive and compete to some extent with traditional hikers. This area is out of bounds for any motorized vehicles, including automobiles, dirt bikes and other types of all-terrain vehicles. Users of the footbridge are typically anglers, hiking groups and clubs, mountain bikers, scout groups, and unorganized or solo hikers. With experienced and inexperienced users of all ages, the footbridge has to be more than a felled tree or log-beam. Enter the Design Outlaws.

The students— Brent Buck, Rich Hall, Ken Huck, Mike Pearson, and Steve Simon— saw the Mosquito Creek crossing as the perfect site for their project. First, there was a trail without a bridge, an acceptable condition for these avid hikers. Second, the District of North Vancouver was considering proposals for designs of bridges to span Mosquito Creek. And finally, the district had conducted a number of studies of the geomorphology of the creek region, all of which were available for public access. After visits to the site over a few days a vision for their project unfolded. A study of the site would be conducted, and with the district's data, a scale model of the site would be constructed. The stream bed and its banks, trees, and the trail would be modelled at a scale of 1 : 25. Criteria would be developed from knowledge of the aquatic life, creek processes, geomorphology, history, and use of the site. Each outlaw would design a scale bridge that could be placed and removed from the site model with ease. The context or the actual site would be an ecological and aesthetic constraint on the bridges' designs. The bridges would be uniquely different, all incorporating features of current designs in structural engineering. The models would be judged on their relation with the site and load bearing capacities would be calculated through an application of engineering theory. The bridges would be presented to the District of North Vancouver as eco-alternatives to consider in the impending decision to place a footbridge at the Mosquito Creek site.

Site Assessments, Site Model, and Eco-Bridges

The students gathered the following data from a site assessment completed by a consulting engineer for North Vancouver. The bridge location is at the apex of a creek fan, meaning that the creek location can suddenly shift during a flood. A berm was constructed in 1991 to mitigate such a change. In general, fan apexes make good locations to bridge a creek providing that the design is sensitive to creek processes. This stretch is subject to large debris-laden floods and debris flows are active in much of the creek. The bridge site is subject to boulder surges and large floating debris. The creek bed moves up and down, plus or minus about three feet, in response to erosion processes and deposition. Peak flow of the creek is about 2,600 cu ft/second at flood stage, a conservative estimate for designing bridge footings. The wider the bridge opening the better with this type of hydraulic flow. This data provided a sense of the geomorphologic considerations going into bridge design.

The students' site assessment consisted of measuring the key elements (boulders, contours, stream opening, trail, trees, etc.) of the site and mapping these elements onto a scale grid. An assessment was made of the local vegetation and the stream bed debris and these elements were mapped onto the grid. Between photos and the site plan, the students were able to assemble a scale model of the site. The grid was transferred onto the base of the model, a 4x8 sheet of exterior plywood.

The contours of the steam bed and surrounding elevations were formed with wire screen and mesh, giving form to the model site. Filler for the elevated contours was made from used boxes, egg cartons, newspapers, and Styrofoam. Plaster of paris was used as a rough surface finish, with additional surface treatments made to place boulders and the trail and to enhance the stream bed. The surface was painted and finishing touches placed trees and vegetation (dead branches made into trees, lichen, moss). Within a few days, the site model came to life and by any assessment was a beautiful, stable representation.

As the site was constructed, criteria were formulated for designing the footbridge and evaluating solutions. Eventually each of the outlaws agreed on the criteria and a matrix for design and evaluation was made. The footbridge had to be or have

- Safe for all intended and unintended uses
- Minimal width of 5 ft
- Deck height designed to a peak flow height plus 6 feet of freeboard
- Durable and have minimally a 40 year life cycle
- Footings protected from erosion
- Minimal debris collection and damage
- Minimal impact on aquatic life during and after construction
- Minimal impact on site condition and vegetation
- Reasonably resistant to damage by vandals
- Aesthetically pleasing while blending into wilderness setting
- Economically feasible

The bridge had to be designed as an entrance way to the trail and set the mood for the experience of the hike. It had to be an inviting structure that does not appear imposing or industrial. In short, the bridge had to be one with the site. With the criteria in hand, each student set off to investigate structural arches, beams, cables, suspensions, and trusses.

Once a range of different structural designs were investigated each student settled on a bridge style. Brent would build a Pratt truss bridge; Rich, a suspension bridge; Ken a post-tensioned wood beam bridge; Mike, an arched beam bridge; and Steve would build a post-tensioned cable bridge. Engineering theory of materials and form guided the initial design process and each student was able to build with an understanding of equilibrium, stability, and strength. The students found that structures where people gather had to be designed to support a minimum live load of 100 lbs./ sq ft. This meant that the bridges had to support a live load of at least 55,000 lbs which would be distributed across the full span. Redundant components appearing in early designs were eliminated in final designs, and given the site. Given that wood performs well in tension but poorly in compression, the bridges were designed with combinations of cable, laminate, and wooden members.

After two weeks, the group had an impressive model of the Mosquito Creek site and five bridges which exploited unique aesthetic, ecological, structural features. Brent exploited a Pratt truss design for his Wooden Truss bridge (Photo 1). The bridge is lightweight and its trusses

are effective for relatively short spans. The diagonal members transmit forces between the vertical chords as forces change between compression and tension when the bridge is traversed. Ken's Wood Beam bridge takes advantage of a post-tensioned cable (Photo 2). The cable compensates for the inadequate performance of the Parallam beams under tension. Mike's Arched Beam bridge exploits the capacities of a laminate (Parallam) to span the creek bed (Photo 3). The load on the arched beams is distributed back to abutments on the adjoining banks. Steve's Post-tensioned Cable bridge uses two lightweight beams to span its 55 ft main section (Photo 4). Similar to Ken's design, the beams are tensioned after building in order to support their strength in tension. The main section is joined with a 20 ft graded section which is offset at 20 degrees. These four designs are a simple, elegant bridges that meet engineering codes and would be relatively inexpensive to build.

Rich's Suspension bridge uses cables to support a mid-span platform which in turn supports two short beams (25 ft each) that extend from opposite towers (Photo 5). The short, light beams are advantageous for construction in wilderness settings. The suspension cables function entirely in tension while the towers function entirely in compression making the bridge both strong and flexible. The platform in the middle of the span provides two extra feet of space on each side of the walkway. This invites hikers to slow-down, stop, and ponder the scenic wonders of the creek both up and downstream of the bridge. The suspension bridge has its own inherent beauty and its simple materials do not detract from the setting. All five designs take advantage of wooden structures that are non-imposing and sit well within the rugged, forested environment.

At the end of the three-week term, the students had an opportunity to demonstrate the utility of their model site and bridges and the beauty of their reconceptualized bridge project. It was a beautiful, sunny afternoon in Vancouver and the perfect environment to talk about bridges, mountain biking and hiking. As the students introduced their project, it was clear that this was a complex endeavor. On top of the materials and structural engineering that they had learned, there were lessons in geomorphology, history, hydrology, politics, soil science, surveying, and

wildlife preservation. At the end of the day, the design outlaws had managed to provide five elegant solutions for the trail setting along with a novel alternative to the bridge project. The students fell short of their intention of presenting their solutions to the District of North Vancouver. In 1998, a cold, pre-fabricated, aluminum bridge was placed in the Mosquito Creek setting.

Life Cycles, Bicycles, and Bridges

The Mosquito Creek footbridge is an excellent example of how a technology education project can be used to transform design cycles into life cycles. As they bridged a stereotypically masculine project with a different way of thinking, our protagonists— design outlaws— bridged the challenges of structural engineering with ecological design. The bridges constructed by the design outlaws were structurally sound and tuned into a setting— they were made to be a part of the environment. The materials and styles chosen were sensitive to the users of the trail and the wildness of the setting. It's important to remember that not only the trail is shared. The setting is shared by bikers, birds, bugs, coyote, fish, hikers, rocks, trees and a host of other participants. Mosquito Creek is not in the way and does not divide the trail— the creek is the setting.

...Let us build a bridge of beauty
Let us cross it with a song
Let us span another canyon
Let us right another wrong...

Oh and if someone should ask us
Where we're off and bound today
We will tell them 'building bridges'
And be off and on our way.
—Bill Staines

Bridging Design and Ecology— Footbridges

Context
For one of our first projects in design, we have been asked to design a footbridge! The bridge has to be designed for an outdoor setting which we will survey and model. We will work in teams of three.

Problem
Design and construct a "footbridge".

Design Constraints
• After visits to the site, and upon building a model of the setting, we will develop a list of constraints together.

Design Considerations
• Pay close attention to appropriate form of materials, simplicity, unity and economy
• Pay close attention to structural design principles and safety codes
• The uses of the bridge *and* its setting are extremely important
• Remember, building or placing the bridge must *not* interrupt the local ecology
*No Sloppy work!

Sequence
• Think about and sketch your designs without worrying too much about structural design—concentrate on the setting
• Choose appropriate materials and structures (Consult your engineering notes)
• Collect the materials that you need
• Be sure you like your design and check to make sure it is workable
• Double-check the constraints on forms and size
• Cut your materials and smooth any sharp edges
• Do your gluing, fastening or welding or painting of individual members before you assemble the bridge
• Assemble pieces temporarily before you complete your bridge
• Place the bridge in the model setting and assess its design

Management Issues
• End of Day 3: Site Assessment completed
• End of Day 5: Model setting completed
• End of Day 6: Approval of design sketches
• End of Day 7: Approval of materials
• End of Day 10: Submit finished bridge for display

• Be sure to obey all safety rules when using tools and machines!
• Remember to be polite to people who help you!

Related Studies
• Drafting and Sketching
• Design
• Geometry
• Materials science
• Structural Engineering
• Ecology
• Surveying

Honest Self Evaluation

1. We stayed within the design constraints and deadlines— _____ out of 5 marks

2. Our bridge is very much like my approved sketch— _____ out of 5 marks

3. Our bridge is stable and functional — _____ out of 5 marks

4. We have a nice display of the principles and elements of design— _____ out of 5 marks

5. Our bridge relates very well to its setting — _____ out of 5 marks

6. Our finished bridge represents quality work— _____ out of 5 marks

7. our use of resources was economic— _____ out of 5 marks

_____ Total out of 35

Assessment

Student's Assessment Student Total _____

Design Principles

- Appropriate Form _____ out of 10
- Simplicity _____ out of 10
- Ecology _____ out of 10
- Economy _____ out of 10

Craft and quality _____ out of 10

Deadlines, Safety and Participation _____ out of 15

_____ Total out of 100

1. We stayed within the design constraints and deadlines— _____ out of 5 marks

2. Our bridge is very much like my approved sketch— _____ out of 5 marks

3. Our bridge is stable and functional — _____ out of 5 marks

4. We have a nice display of the principles and elements of design— _____ out of 5 marks

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Assessment

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Craft and quality _____ out of 10

Deadlines, Safety and Participation _____ out of 15

_____ Total out of 100

[1]Otis W. Caldwell and Stuart A. Courtis, *Then and Now in Education, 1845: 1923* (New York, 1924), 155; See also H.R. Gray, "Improved Learning Aids and Future Educational Reorganization," *Teachers College Record* 43 (1936): 599-602; Howard McClusky, "Mechanical Aids to Education and the New teacher—A Prophecy," *Education* 55 (1934: 83-88; "Professor Reynolds Holds That Modern School Fits Pupils for Machine Age," *Teachers College Record* 32 (1930): 649-651.

[2]Joy Elmer Morgan, "The School of Tomorrow," *Journal of the National Education Association* 18 (1929): 1

[3]John Dewey & Evelyn Dewey, *Schools of Tomorrow* (New York, 1915).

[4][Sidney L. Pressey], "First Results With, and Problems in the Development of, Apparatus for Testing and Automatic Experimentation in Learning," [summer, 1930], p. 2, 40/49/4/21, Pressey Papers, The Ohio State University Archives.

[5]David Dwyer, "Apple Classrooms of Tomorrow: What We've Learned," *Educational Leadership* 51 (April, 1994): 9. See also Marvin Cetron, *Schools of the Future* (New York, 1991), pp. 1-35.

[6]In 1962, Finn, Perrin , and Campion wrote "the American educational enterprise exists out of technological balance with other great sectors of the society. As such, it can be viewed as a relatively primitive or underdeveloped culture existing between and among highly sophisticated technological cultures." James Finn, Donald Perrin, and Lee E. Campion, *Studies in the Growth of Instructional Technology*, I, National Education Association Technological Development Project (Washington, DC, 1962), 1. And today, much of CAI rhetoric is similar, if not identical, to Pressey's of the 1930s. "There's a revolution going on," Lewis Perleman wrote in 1990, "teachers must now decide what role they will play, vanguard, victim, leader, or Luddite." Quoted in Michael Schrage, "Nintendo Educators Miss the Real Mission of the Schools," *The Washington Post* (Friday, 14 December 1990): F3.

[7]Douglas Noble, "The Underside of Computer Literacy," *Raritan* 3 (1984): 57.

[8]Cover quotes John T. Bruer, "The Mind's Journey From Novice to Expert," *American Educator* 17 (Summer 1993): 8.

[9]e.g.,, Michael Apple, "The New Technology: Is it Part of the Problem or Part of the Solution?," *Computers in the Schools* 8 (1991): 59-81; C.A. Bowers, *The Cultural Dimensions of Educational Computing: Understanding the Non-neutrality of Technology* (New York, 1988); Mary Bryson & Suzanne De Castell, "Learning to Make a Difference: Gender, New Technologies and In/Equity," *Mind, Culture, and Activity* 3 (1996): 119-135; David Cohen, "Educational Technology, Policy and Practice," *Education Evaluation and Policy Analysis* 9 (1987): 153-170; Suzanne Damarin, "Unthinking Educational Technology: A Feminist Perspective," *Holistic Education Review* 7 (1994): 51-57; John Beynon & Hughie Mackay, eds., *Technological Literacy and the Curriculum* (New York, 1992); Hughie Mackay, Michael Young & John Beynon, eds., *Understanding Technology in Education* (New York, 1991); Marita Moll & Heather-jane Robertson, "Backwash From the Technological Wave," Paper presented at Annual Learneds Conference, Memorial university, St. Johns Newfoundland, 12 June 1997; Neil Postman, Virtual Students, Digital Classroom," *The Nation* (9 October 1995): 377-382; Leonard Waks, "The New World of Technology in US Education: A Case Study in Policy Formation and Succession," *Technology in Society* 13 (1991): 233-253.

[10]Michael W. Apple, *Teachers and Texts: A Political Economy of Class and Gender Relations in Education* (New York, 1986); Michael W. Apple and Linda K. Christian-Smith, eds. *The Politics of the Textbook* (New York, 1991); Suzanne de Castell, Allan Luke and Carmen Luke, *Language, Authority and Criticism: Readings on the School Textbook* (New York, 1989); David Elliott and Arthur Woodward, eds., *Textbooks and Schooling in the United States*, 89th Yearbook of the National Society for the Study of Education, part I (Chicago, 1990); Allan Luke, *Literacy, Textbooks and Ideology: Postwar Literacy Instruction and the Mythology of Dick and Jane* (New York, 1988); Special issue "Embattled Books: The State of the Text," *Journal of Educational Thought* 24 (1990).

[11]Rebecca Barr and Robert Dreeban, "Instruction in Classrooms," in *Review of Research in Education*, ed., Lee Shulman (Ithaca, IL, 1977), 89-156; Rebecca Barr and Robert Dreeban, *How Schools Work* (Chicago, 1983); Gary Burtless, ed., *Does Money Matter?* (Washington, DC, 1996).

[12]Commercialization, commodification, and commoditization have been used somewhat interchangeably by contemporary analysts of education. For David Noble, commercialization refers to the larger process of aligning education with business and industry while commoditization refers to the process of transforming instructional practice into material and symbolic forms (i.e., courses become courseware). Commodification typically refers to the reduction of education, knowledge, or work to economic and market processes. For this essay, commodities will generally be those artifacts (architectural, administrative and instructional) that order and shape educational practice. Commodification will refer to the larger process of the production and consumption of these artifacts and spaces and their symbolic capital. On these issues, see David Noble, "Digital Diploma Mills: The Automation of Higher Education," [Electronic document, 1997], Available from http://www.journet.com/twu/deplomamills.html; Wesley Shumar, *College for Sale: A Critique of the Commodification of Higher Education.* (Washinton, DC, 1997). I will deal with K-12 classrooms, acknowledging the differences involved in the commodification of post-secondary education in North America. I will *not* review histories of classrooms and technologies installed for the working classes, such as artrooms, pottery wheels, shops, milling machines, kitchens, stoves, offices, and typewriters.

[13]Author, "Psychology, Technology and Clinical Procedures in Education: The Cases of Luella W. Cole and Sidney L. Pressey, 1917-1934" (Ph.D. diss., University of Maryland, 1994); Author, "'The Never-To-Be-Forgotten Investigation': Luella Cole, Sidney Pressey and Mental Surveying in Indiana, 1917-1921," *History of Epsychology* (under review); Author, "From Intelligence Testing Machine to 'Automatic Teacher': Sidney Pressey and Failure in the Commercialization of Psychological Apparatus, *Technology and Culture* (under review); Author, "'The Best Known Couple in Our Field': Luella Cole, Sidney Pressey and the Construction of

'Educational Psychology' at The Ohio State University, 1921-1932," *Journal of the History of the Behavioral Sciences* (under review); Author, *Medicalizing Liberty and the Soul in the 'Kingdom of Evils': Education, Medicine, Psychology, Liberty, 1910s-1930s* (unpublished manuscript, 1999).

[14]Bruno Latour, The Costly Ghostly Kitchen," in *The Laboratory Revolution in Medicine*, eds. Andrew Cunningham & Perry Williams (Cambridge, 1992), 295-296.

[15]Gilbert B. Morrison, "School Architecture and Hygiene," in *American Education*, ed. Nicholas Murray Butler (New York), 430

[16] Henry Bernard, *School Architecture* (New York, 1848).

[17]May Ayres, Jesse Williams and Thomas Wood, *Healthful Schools* (New York, 1918); Severance Burrage and Henry T. Baily, *School Sanitation and Decoration* (New York, 1899); John Duffy, *The Sanitarians: A History of American Public Health* (Urbana, IL, 1990), pp. 175-220; John Duffy, "School Buildings and the Health of American School Children in the Nineteenth Century," in *Healing and History*, ed. Charles Rosenberg (New York, 1979); Suellen Hoy, *Chasing Dirt, The American Pursuit of Cleanliness* (Oxford, 1995), pp. 87-149; W. Kilham, "The Hygienic Construction of Schoolhouses from an Architect's Standpoint," *Fourth International Congress on School Hygiene Transactions*, volume II (1914): 35-38); Morrison, "School Architecture and Hygiene;" Edward Shaw, *School Hygiene* (New York, 1901); Grant Rodwell, "Australian Open-Air School Architecture," *History of Education Review* 24 (1995): 21-41; Nancy Tomes, *Gospel of Germs: Men, Women and American Life* (Cambridge, MA, 1998); Nancy Tomes, "The Private Side of Public Health: Sanitary Science, Domestic Hygiene, and Germ Theory, 1870-1900," *Bulletin of the History of Medicine* 64 (1990): 509-539.

[18]Philip Lovejoy, "Securing Efficient Janitorial Service," *The Nation's Schools* 3 (1929): 17.

[19]Thomas Markus, *Buildings and Power: Freedom and Control in the Origin of Modern Building Types* (New York, 1993), p. 93; Thomas Markus, Early Nineteenth Century School Space," *Pedagogica Historica* 32 (1996): 1-50.

[20]Ibid, 94; See also Ian Hunter, *Rethinking the School* (St. Leonards, NSW, 1994), 9-10, 72-75.

[21]William W. Cutler, "Cathedral of Culture: The Schoolhouse in American Educational Thought and Practice Since 1820," *History of Education Quarterly* 29 (1989): 1-40.

[22]Deborah Weiner, *Architecture and Social Reform in Late-Victorian England* (Manchester, 1994): 148; See also Edward R. Robson, *School Architecture* (Leicester, 1874). On these themes, see also Malcolm Vick, "Building Schools, Building Society: Accomodating Schools in Mid-Nineteenth Century Australia," *Historical Studies in Education* 5 (1993): 231-250.

[23]Rhodri Windsor-Liscombe, "Schools for a 'Brave New World': R.A.D. Berwick and School Design in Postwar British Columbia," *BC Studies* 90 (1991): 25-39.

[24]John B. Parkin, "Tomorrow's Schools," *Royal Architectural Institute of Canada Journal* 20 (1943): 99-114.

[25]e.g., Barr and Dreeban, *How Schools Work*; (n. 10 above); Burtless, *Does Money Matter?*, (n. 10 above); Ian Westbury, "Research into Classroom Processes: A Review of Ten Years' Work," *Journal of Curriculum Studies* 4 (1978): 283-308.

[26]On black-boxing of technology, see Bruno Latour, *Science in Action: How to Follow Scientists and Engineers Through Society* (Cambridge, MA, 1987), 1-17; Nathan Rosenberg, *Exploring the Black-Box: Economics, Technology and History* (Cambridge, 1994).

[27]See e.g., Brabara Finkelstein, "Education Historians as Mythmakers," in *Review of Research in Education* 18, ed. Gerald Grant (Washington, DC, 1992), 275, 286.

[28]Barbara Finkelstein, *Governing the Young* (New York, 1990), 10.

[29]David Hogan, "The Market Revolution and Disciplinary Power: Joseph Lancaster and the Psychology of the Early Classroom System," *History of Education Quarterly* 29 (Fall 1989):

381-417; David Hogan, "Examinations, Merit, and Morals: The Market Revolution and Disciplinary Power in Philadelphia's Public Schools, 1838-1868," *Historical Studies in Education* 4 (Spring 1992): 31-78; David Hogan, "The Organization of Schooling and Organizational Theory: The Classroom System in Public Education in Philadelphia, 1818-1918," in *Research in Sociology of Education and Socialization*, ed. Ronald Corwin (Greenwich, CT, 1990), 241-294.

[30]Hogan, "The Organization of Schooling," 278.

[31]See also Keith Hoskin, "The Examination, Disciplinary Power and rational Schooling," *History of Education* 8 (1979): 135-146; Karen Jones and Kevin Williamson, "The Birth of the Schoolroom," *Ideology and Consciousness* 6 (1979): 59-109; Alan Kazdin and Joan Pulaski, "Joseph Lancaster and Behavior Modification in Education," *Journal of the History of the Behavioral Sciences* 13 (1977): 261-266.

[32]David Hamilton, "Adam Smith and the Moral Economy of the Classroom System" *Journal of Curriculum Studies* 12 (1980): 282; David Hamilton, *Towards a Theory of Schooling* (New York, 1989).

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