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Multidisciplinary Technology Education

STEPHEN PETRINA

University of British Columbia, Department of Curriculum Studies, 2125 Main Mall, Vancouver, BC V6T 1Z4, Canada. E-mail: spetrina@unixg.ubc.ca

ABSTRACT: Contrary to a tale that is being told in the US, there is no transhistorical, universally pristine organisation of technology. This article resituates technology education in the contested, historico-political terrain to which it belongs. The current, and only, model of the technology discipline is interrogated in order to interrupt a project with roots bound up with a doctrinaire, academic conservatism popularised during the early 1960s. Following a lively critique of the technology mono-discipline, comparative curriculum is used for path-finding and interpretation. Counter to the mono-discipline model of technology, the conceptual parameters of a critical and plural multidiscipline are outlined. 'Multidisciplinary Technology Education' (MTE), inspired through efforts in art education, is proposed as a middle path between the technology mono-discipline and Design and Technology. MTE is balanced over four interdisciplines – Practice, Design, Studies and Criticism – with an end in technological sensibility and political sagacity.

Keywords: multidisciplinary technology education, design, technology studies, critique of disciplines, art education, comparative curriculum, politics of curriculum

> [I]f disciplines are such by virtue of a historically contingent, adventitious coherence of dispersed elements, then to study that coherence is necessarily to begin questioning portrayals of disciplines as seamless, progressive, or naturally 'about' certain topics. In studying disciplinarity, one defamiliarizes disciplines . . . (Messer-Davidow, Shumway & Sylvan, 1993, p. 3).

In this article, the technology discipline will be resituated in the contested, historico-political terrain to which it belongs. I'll interrogate the current, and only, model of this discipline in order to interrupt a project rooted in a doctrinaire, academic conservatism popularised during the early 1960s. In direct opposition to this troubled, mono-disciplinary model of technology, the conceptual parameters of a critical 'counter multidiscipline' will be outlined. In the final analysis, it will be argued that curriculum organisation – what is *selected* to be taught and how it is *organised* to teach – is a moral and political endeavour, and much less an epistemological issue. There is *not* a 'natural', logical way to organise technological knowledge; there are simply political choices and rhetorics. Contrary to a tale that is being told in the US, there is no transhistorical, universally pristine organisation of technology.

The article is bound up with my own frustration with the binary presented over the last decade concerning, on one hand a framework for the discipline of technology, and on the other, the proclaimed 'content-free' curriculum of Design and Technology (D&T) (Shield, 1996, p. 55). In the US, there has been merely a brief ‘yes technology is a discipline – no it is not’ style of discussion, ignoring the political issue of whether the current framework is democratically sensible at this point in time. I’ll argue that in the late 1990s, the issues of whether technology is a discipline and the current framework are out-dated. In England, Ireland and Wales, it appears that discussion has revolved around organising processes in D&T, sidestepping the disciplinary issues of content altogether. I’m proposing a middle path through spaces between the current framework for the discipline of technology and D&T. I’m also proposing a middle path through the dichotomy set up between academic and vocational education in North America, or academic and practical knowledge. For my purposes, in the spirit of comparative curriculum, I will follow the path-finding efforts of art educators over the few decades.

DISCIPLINES, DISCIPLES, AND DOCTRINE

Disciplining disciples

At the dawn of the 1960s in US history, the Cold War was entering the second decade of its full career, and American education was on the defence. A series of polemical indictments against education published in the mid to late 1950s, like Arthur Bestor’s *Educational Wastelands* and *The Restoration of Learning* and Vice Admiral Hyman Rickover’s *Education and Freedom*, championed traditional academic learning and intellectual training. Resulting panic helped legitimate a retreat toward the order and control afforded through the likes of Bloom’s *Taxonomy of Educational Objectives*, Skinnerian teaching machines and programmed learning, and disciplinary taxonomies. Essentialism was on the ascent.

In the first year of this decade, Jerome Bruner published *The Process of Education* (Bruner, 1960). In this small book of less than 100 pages was an outline of a theory for disciplinary structure, an idea which would quickly become enormously influential as a ‘curriculum manifesto’ (Pinar et al., 1995, p. 159). The book was generally a report of a conference in 1959 on reform in math and science education, sponsored by policy groups including the National Academy of Sciences, National Science Foundation, Air Force and Rand Corporation. Bruner argued that academic disciplines exhibited an innate structure which held the key to student understanding and retention of knowledge.

During the next few years, dozens of rationales arguing Bruner’s points were articulated. Conferences and symposia were held and by 1963, the structure of the disciplines had already been canonised as the natural avenue for curriculum organisation (Efland, 1988; Pinar et al., 1995, pp. 168–177). Two influential supporters of this disciplinary organisation of curriculum published papers in 1962. Joseph Schwab published ‘The Concept of the

Structure of a Discipline' and Philip Phenix 'The Use of the Disciplines as Curriculum Content' (Schwab, 1962; Phenix, 1962). Several major texts had been published by 1966, including King & Brownell's *The Curriculum and the Disciplines of Knowledge*. 'Teach the disciplines' and derive content from disciplinary structure was the doctrine of the time. Indeed, 'disciplinary doctrine' and subjugation would hold that 'the chief if not the sole criterion for including any subject in the school curriculum is whether that subject is recognised as an academic discipline' (Tanner & Tanner, 1989, p. 341). Explication of disciplinary structures and taxonomies of content was the first step on this new path. Disciplinary proof would be decisive in what and who counted as a subject. Directions for becoming a discipline had been defined and laid out step by step (Shermis, 1962).

This is generally the context in which two proposals were made to align industrial education with disciplinary doctrine in the US. Paul DeVore published his 24 page monograph titled *Technology: An Intellectual Discipline* in 1964. In 1966, Edward Towers, Donald Lux, and Willis Ray published *A Rationale and Structure for Industrial Arts Subject Matter*, a 382 page document. 'Industrial praxiology' or 'industrial technology' was the discipline for what Towers, Lux and Ray called the Industrial Arts Curriculum Project (IACP) (1966, p. 42). DeVore was completing his doctoral studies at Pennsylvania State University at the time he intiated his proposal. The IACP began as an effort divided between The Ohio State University and the University of Illinois. DeVore's logic was familiar and perfectly attuned to the new manifesto: 'By becoming an intellectual discipline an area becomes accepted as a necessary and contributing study in the education of all youth' (DeVore, 1964, p. 5). He concluded that technology sufficiently met Shermis' criteria and was an intellectual discipline, so long as a structure was articulated. Similarly, Towers, Lux and Ray were 'committed to the belief that a structured body of knowledge does exist' for industrial technology (1966, p. 239). '[O]ne of the most important tasks' remaining was its 'complete and detailed structuring' (p. 78). For both DeVore and the IACP directors, students were to act and think as little industrial technologists working within a discipline, true to disciplinary doctrine.

A structure for industrial technology was articulated in the IACP, based on analysis of economic classification systems. Industrial technology in the IACP was divided into 'construction' and 'manufacturing', which in turn was sub-divided into management, personnel and production. These sub-divisions sub-divided and so on (Figure 1). This discipline would provide a logical basis for the selection of curriculum. By 1966 and 1968 respectively, the equivalents of the sciences for the disciplines of industrial technology and technology had been more or less fully constructed.

For structural direction, DeVore turned to biology, the paradigmatic discipline of classification and taxonomy. Technology would divide into 'Areas' of 'Production, Transportation, [and] Communication'. The production area would sub-divide into 'Divisions' of 'Manufacturing [and]

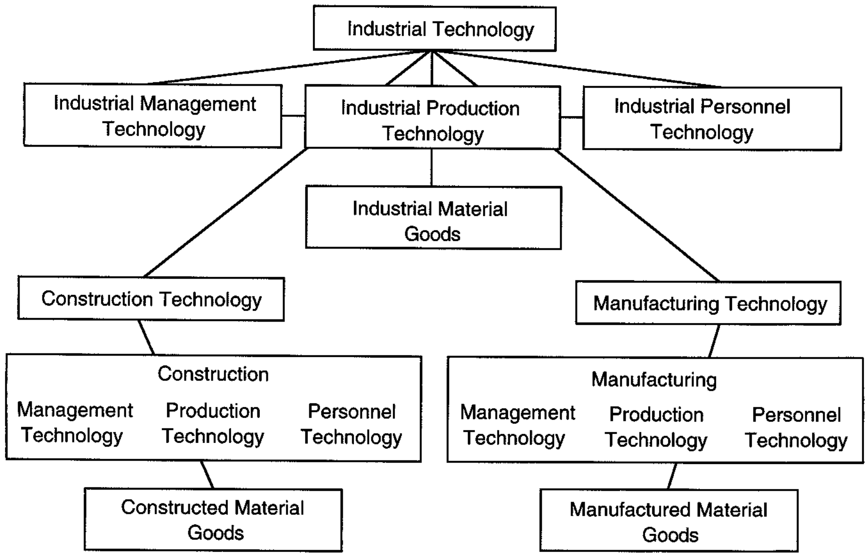

Figure 1. Structure and taxonomic organisation of knowledge for the mono-discipline of industrial technology in the IACP. Note that economic or industrial 'services' are *not* included as 'major structural elements' in the discipline. Cognate disciplines, like industrial sociology and industrial psychology, would not be integral to student understanding. Adapted from Towers, Lux & Ray (1966, p. 167).

Construction;' manufacturing into the 'Category' of 'Fabrication [and] Processing'; fabrication into five 'Departments' and *etcetera* for five more taxonomic steps (DeVore, 1968a, pp. 13–15). This structure would provide the student of technology with an understanding of the discipline (Figure 2). It would also provide teachers with a 'basis for valid content selection' (p. 16).

Towers, Lux and Ray distanced themselves from DeVore by centering their discipline on industry (1966, pp. 60–61). They recognised 'practice' as an essential component of a 'practical' discipline, and reasoned that industrial technology reflected industrial education more accurately than DeVore's discipline. Nevertheless, both industrial technology and technology were conceived as mono-disciplines: they were designed to isolate technology from other domains and forms of knowledge. While some educators were founding their subjects on multiple disciplines in the 1960s, technology was found and continued to be articulated as a mono-discipline. This articulation occurred amidst the student protests and near anarchic reactions to the irrelevance of isolating disciplines and (dis)integrating knowledge in the 1960s (DeVore, 1967, 1968, 1970; Lux and Ray, 1970, 1971).

Bruner, Phenix and Schwab however, rethought their original ideas by the late 1960s. Bruner (1971, p. 19) went so far as to call for a moratorium on disciplinary structures founded on his original proposal, such as DeVore's technology and industrial technology in the IACP. Phenix revised

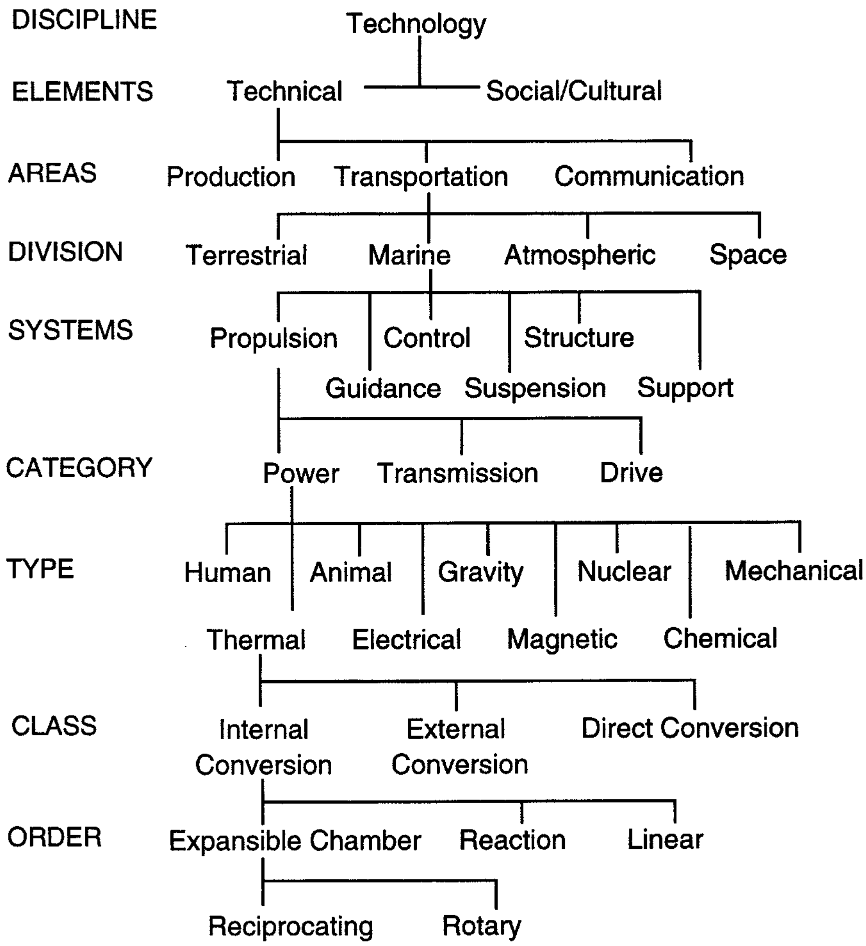

Figure 2. DeVore's structure and taxonomic organisation of knowledge for the mono-discipline of technology (transportation 'area' example). Note that the 'social-cultural' element of technology is (and continues to be) neglected and undefined, while 'technical' elements are structured and uncontested for communication, production (construction and manufacturing) and transportation industries. Adapted from DeVore (1980, p. 247).

his ideas by concluding that disciplinary studies tend toward 'a sense of academic irrelevance' (1969, p. 13). Schwab noted the 'abstracted, idealised' nature of disciplinary content, and its foundation in 'habits of the academic community' as much as anything else (1969, p. 225). But as they realised, disciplinary doctrine and subjugation had taken on a wide core of disciples.

In industrial education through the 1970s, DeVore's discipline was localised within his immediate environment at West Virginia University (WVU). The discipline of Towers, Lux and Ray was used routinely in about 2,700–3,000 junior high schools in the US by the late 1970s (Lux, 1979).

It wasn't until the early 1980s, in the midst of another essentialist panic and educational crisis created through polemics such as *A Nation At Risk*, that interest in the technology discipline would be resurrected. A so-called 'Meeting of the Minds' was held in 1981 to found industrial arts (industrial education) on disciplinary doctrine (Wright, 1995, p. 257). DeVore and Ray were among the 20 men who met, and DeVore's mono-discipline had won over that of Towers, Lux and Ray (Hales & Snyder, 1982). The logic of both efforts of the 1960s was embedded in the 'rationale' and 'structure', and disciplinary doctrine undergirded the resultant 'Jackson's Mill' framework. By the next 'Meeting of the Minds' which ended in a consensus in 1989, this structure and doctrine pervaded the International Technology Education Association's (ITEA) official curriculum (Wright, 1995, p. 257). In addition to structure, this group of twenty-five fabricated something called 'the technological method,' covering the perceived weak pavement on the road to disciplinary status (Savage & Sterry, 1990, p. 13; c.f., Petrina, 1993, 1994).

The new disciples, including students of DeVore and the IACP had turned to the disciplinary doctrine scripted in the late 1950s and 1960s. Retired scholars, such as Walter Waetjen, whose disciplinary work began in the early 1960s, turned agitators for the technology discipline in the 1990s (Waetjen, 1992, pp. 25–30). 'Technology is a discipline' enthusiastically declared William Dugger, echoing DeVore's rhetoric of 25 years (Dugger, 1988, p. 5). This is not to say that technology has attained disciplinary status (Lewis, 1995; Zuga, 1994, p. 66).

Dugger and DeVore, with professed credulity, have secured US government funding for a framework embodying the technology mono-discipline. The National Science Foundation (NSF) made an intial grant of $1.5 million (US) to the project for the 1994–1996 period, and will continue to fund the effort at about $500,000 per year through 1999. NSF funds are supplemented by capital or funds from the Technical Foundation of America and the ITEA. The latter two organisations are directed by vocal disciples of the mono-discipline. The funded, disciplinary endeavour, or 'Technology For All Americans (TFAA) Project', is under direction of Dugger. DeVore is one of the project's 25 national commissioners and six writing consultants. The first phase of the project has the indelible mark of the mono-disciplines of the 1960s. The rhetoric arguing that 'technology is a discipline' has been embedded in the project, with a few minor adjustments made to the structure of the 1960s (*Technology for all Americans* (*TFAA*), 1996). Earlier taxonomic divisions (i.e., Communication, Construction, Manufacturing, and Transportation industries) were reconfigured as information, physical, and biological industries. The rhetoric continues to be about taxonomic 'universals of technology', as these disciples evidently believe that they are working with a transcultural and transhistorical subject (*TFAA*, 1996, p. 16).

Since the reconciliation of DeVore's discipline with industrial technology of the IACP in 1981, there has not been a single counter-discipline. Criticism of disciplinary doctrine has been virtually non-existent (c.f., Herschbach, 1995, 1997; Petrina, 1993). But the technology mono-discipline has *not* been acknowledged outside of technology education or the US.

As one disciple recently lamented: ‘Outside the fields of technology education and the philosophy of technology, however, there appears to be little awareness, interest, or acknowledgement that technology is a discipline’ (Bensen, 1995, p. 3). But he’s grasping, and one wonders what philosophy of technology he is talking about (not indicated). Philosophers of technology have not been the least bit interested in ‘acknowledging’ that technology is a discipline. Nor have philosophers preoccupied themselves with the details of disciplinary taxonomies for technology. The latest synthesis of the philosophy of technology by Mitcham (1995), does not in any way even allude to an academic ‘discipline’ of technology. In fact, the opposite is true of Mitcham and most others in Science and Technology Studies: there is nothing natural about any discipline, including that of science or technology. Contriving a discipline is a political and problematic act.

Nonetheless, the TFAA Project and most of what is conventional wisdom in the US regarding technology education is underpinned by a consensus toward the technology discipline as constructed in the 1960s (DeVore, 1992; Dugger, 1988; Gray, 1989; Hales & Snyder, 1982; c.f., Petrina, 1997a; Savage & Sterry, 1990; Technology Education Advisory Council (TEAC), 1989; Wright, 1992). The mono-discipline of technology is strictly speaking, a fabrication contrived by educators who part and parcel were bound up with the disciplinary doctrine and subjugation of the early 1960s and 1980s. Evidence for disciplinary taxonomy and status from 1964, 1966, 1968 or 1988 is wanting by today’s standards; or worse, it’s thirty-five years too late. The mono-discipline card played by the disciples in an era of severe threats to their subject is *not* an epistemological, but a despondent, political card. In exchange for resources and status, these technology educators are willing to forgo historical intentions of breaking academic traditions (Petrina & Volk, 1995a, 1995b). The contentions here are whether it’s democratically fruitful to teach technology *via* the mono-discipline offered by the ITEA, and whether the contrivance makes good curricular sense in the late 1990s (Petrina, 1993, 1994).

Theory tales about the disciples’ good behaviour

According to the socio-historical, curriculum theory of Ivor Goodson (1992, 1993), technology educators behaved over time as we would theoretically expect. Practitioners within industrial education continually shifted the boundaries of what counted as legitimate knowledge, shaping the subject’s identity, form and content. In the early 1960s, amidst a strong essentialist influence and competing versions of industrial education, a disciplinary structure and rhetoric for technology were constructed. Technology emerged as a contender for disciplinary curriculum. As essentialism was resurfaced for the 1980s, the efforts of some industrial educators to accumulate privilege and status by appealing to disciplinary doctrine were efforts to nominate new disciplinary knowledge for power in a competitive system of schooling. Practitioners according to Goodson, invariably over time seek legitimacy for their subjects through appeal for disciplinary status. They ‘move away from the concerns with “utilitarian” or “relevant” knowledge’ (1993, p. 197). Disciples within official academic disciplines, already without those concerns and with high status reinforced through tight university relations, are obviously reluctant to share resources and acknowledge privilege. Thus far, the right university group has yet to confer the privileges of disciplinary status to technology, as that is what it *seems* to take in Goodson’s final analysis. Curriculum is always a contested struggle, but the disciplinary tradition holds the status and resources for survival. In the end, says Goodson, the process of seeking and gaining disciplinary status is one of politics and history. These politics however, extend to the local level of schools and departments.

On a micro level of analysis such as that of Leslie Santee Siskin (1994), technology educators also behaved over time as we would theoretically expect. When DeVore and the IACP directors turned to disciplinary doctrine for direction, they had overlooked traditions and the primacy of practice in their school subject. The subject’s early proponents in the US, such as John Dewey and Frederick Bonser, were seeking to break academic traditions, and aligned with radical notions of education in a democracy (Petrina & Volk, 1995a, 1995b). The technology and industrial technology monodisciplines were a contradiction of these notions. The subject’s constituents were by and large, working class boys, taught by men from working class backgrounds. Instead of an engagement with critical knowledge necessary for working class empowerment and citizenry, DeVore and the IACP directors abstracted the curriculum for disciplinary knowledge; and, in effect made a Procrustean move of trying to fit industrial education into a disciplinary bed. Towers, Lux and Ray acknowledged the tradition of ‘practice’, but turned this into support for the construction of a ‘practical’ or ‘applied’ discipline based on praxiology (1966, pp. 17, 14). Practice in the IACP warranted a methodologically minor role as opposed to a major structural position in the discipline. Practice in the schools, however, was based neither on an ‘intellectual’ nor ‘praxiological’ discipline. It was not a study of accomplished action, as praxiology may suggest. The school teachers had practised industrial education with a handicraft and vocational focus, and formed school departments to institutionally undergird this practice. For these teachers, on their own local level of departments and constituents, a taxonomic structure of content made no difference in their identity and existing relations with other departments. They were probably quite comfortable with their station in schools as ‘shop teachers’. The disciplinary idea probably appeared somewhat awkward to a profession of educators with a history of project organisations of curriculum. The shop teachers had to be persuaded to subscribe to disciplinary doctrine on their local level.

Their subject, industrial education, was already an established subject, with an existing level of support and status. But if the status was low, it was an issue of the sociology of class and the politics of knowledge, and not something that disciplinary doctrine could fix. According to Siskin, gambling on the technology or industrial technology disciplines may not be worth the threat to the *status quo* of the school department and values of the practitioners. For Siskin and others who deal with school level analyses, curriculum is about local politics.

With a lens cast through the 'Actor-Network Theory' (ANT) of Bruno Latour (1987), technology educators can once again be seen as behaving as we would expect. In ANT, various interests are *translated, relevant actors* and *actants* (non-human) are *enrolled* into *networks*, and in the process, *mobilised* for support against competing networks. The US national scene in the mid to late 1960s involved at least a dozen competing efforts that included Don Maley's *Maryland Plan*, Wesley Face's and Eugene Flugg's *American Industry Project*, along with the discipline of Towers, Lux and Ray, and DeVore's discipline (Cochran, 1969a, 1969b; Herschbach, 1995, 1997; Householder, 1979). In effect, enrolling the government, teachers, teacher educators, parents, and students into any one network was a difficult task.

DeVore's 'technology' and the 'industrial technology' of the IACP represented two competing, disciplinary versions of industrial education. From 1967, DeVore began to enroll his colleagues and students at WVU, and translate their interests into disciplinary doctrine. Relying on the power of logic but misunderstanding the power of politics, DeVore constructed the technology mono-discipline as an idea whose time had naturally arrived. In the 1960s, as in any other time, logic and nature were not enough to convince 'relevant actors'. DeVore had much more politicking to do to match the network of administrators, courses, government, industrialists, school teachers, teacher educators and textbook publishers that enveloped the IACP. Towers, Lux and Ray on the other hand, evidently understood the politics neccessary to mobilise for innovation success. They began by translating the interests of those in the US Office of Education (USOE) into their disciplinary proposal, and received funding through the Vocational Education Act in 1965. By 1971, the IACP network had grown to include $2 millon (US) in USOE funds and $100, 000 (US) from other sources, graduate students, teacher educators, engineers, trades unions and textbook companies, textbooks and instructional materials. Between 1970 and 1975, 8,000 teachers, 125 colleges and universities, 2,700 junior high school buildings, and about 2.1 million students were mobilised in the network (Lux, 1979). The IACP network disintegrated during the late 1970s.

According to ANT, innovation networks die hard; or components simply linger until another network of actors, financial or otherwise, is formed to be competitive with dominant networks. In this case, enough disciples had been enrolled through DeVore's and the IACP's efforts to keep their disciplines attractive for over 30 years. It will remain to be seen whether the ITEA, NSF, the National Aeronautics and Space Agency (NASA), the Technical Foundation of America and industrial representatives are in fact *the* relevant actors for the TFAA mono-disciplinary network to succeed. Cultural and financial ($3 million, US) capital of the ITEA, NSF and NASA are actants with persuasive power, but *not* guarantors of success. It also remains to be seen whether DeVore and Dugger, who are mobilised as spokesmen for the discipline of technology, are the relevant actors for translating these varied interests into the now official disciplinary version of technology. Nonetheless, like Goodson's and Siskin's final analyses, ANT suggests that curriculum organisation is about politics (Hepburn, 1996).

Theoretically then, technology educators in the US are behaving as predicted and hoping for the reward that disciplinary doctrine promises. By appealing to a transhistorical notion of a technology discipline and its accompanying doctrine, they have ignored the culturally embedded history of their subject and its teachers. They've led themselves to believe that curriculum follows the logic of a discipline. They've opted to close discourse, moving the weight of the ITEA behind a single, mono-disciplinary version of technology. These new disciples have not recognised, as Towers, Lux and Ray (1966) did, that there are any number of taxonomic orders of technology; all of which are political in serving a particular purpose (pp. 64, 77–78). Whereas in the 1960s and 1970s, dozens of competing curriculum projects flourished in the US, the TFAA Project is now the 'only game in town'.

PATH-FINDING THROUGH COMPARATIVE CURRICULUM

> Certain groups are 'kept in their place' by their failure to master the 'truths' enshrined in the disciplines. But once these disciplines are correctly seen to be human artefacts, their legitimacy is called into doubt, and with it the unequal society that fosters the appearance of that legitimacy (Schrag, 1992, p. 288).

Disciplinary doctrine and its discontents

When disciples in industrial education aligned themselves with a disciplinary doctrine rooted in academic conservatism, they looked to 'science' education as an exemplary discipline. Parroting the rhetoric of the 1960s, Wright exclaimed in 1992 (p. 68): 'The challenge to all technology educators is to apply the same logic as science uses to determine the curriculum focus and structure for the study of technology' (c.f., Petrina, 1993). Persuaded by the disciplinary rhetoric of science of their time, DeVore relied on biology, and the IACP directors on economics, for taxonomic direction. Thomas Kuhn's reading of science as outlined in *The Structure of Scientific Revolutions* was applied to industrial education (DeVore, 1970, p. 20; c.f., Frey, 1992). Like the mono-disciplines of science (e.g., biology, chemistry, physics, etc.), technology became a mono-discipline. In the late 1980s, technology educators conflated technological activity with scientific method. A more recent example is *Technology for all Americans*; which was in fact, if not in form, stamped out of the American Association for the Advancement of Science's *Science for all Americans* project of the late 1980s (Rutherford & Ahlgren, 1989). 'Science' for these technology educators was, and remains, the supreme discipline, and 'science' education the exemplary school embodiment of this discipline.

Science education is a questionable exemplar, and is one of the more problematic of all disciplines in terms of curriculum entrenchment and irrelevance. Criticism is directed at the élite and gendered nature of science education, its mono-disciplinary outlook, its false and abstracted representation of scientific practice, its reliance on a rhetorical scientific method, and its inability to engage a wide range of students. Critical views have been generated within and outside of science education proper (e.g., Brush, 1989; Garrison & Lawwill, 1993; Gough, N., 1993b; Harding, 1986, 1991; Jardine, 1993). Science education in the mid to late 1800s, often in the form of the mechanic arts and 'natural philosophy' of everyday objects, was oriented toward apprentices, workers, and common schools. While its beginnings were shared with industrial education and with working class interests in the late 1800s, it had become by the 1950s steeped in the academic traditions that the early proponents of industrial education were trying to break (Layton, 1973; Stevens, 1995). Science educators may have rationalised disciplinary changes on faulty practices of an earlier era, but neglected to address class interests. Today, science education is situated in disciplinary comfort, but is chock full of problems in spite of this status. But identifying shortcomings within science and science education do not make for a critique of the entire enterprise of disciplinary doctrine.

Critiques made in the late 1960s by the early architects of disciplinary doctrine remain relevant. A notion that disciplinary organisations tend toward fragmentation and a sense of irrelevance, as reflexively adopted by Phenix, is self-evident. Integrative knowledge offers a powerful antidote in a continually (dis)integrated world. Phenix had become a vocal advocate for multi- and interdisciplinary studies over the traditional mono-disciplinary ideas. Bruner's eventual position that disciplines fall far short in addressing pervasive social inequities and problems seems a truism in the late 1990s. For Schwab, the taxonomic divisions reinforced a 'conservative' and élitist curriculum, and was biased against practical and artistic knowledge (1969, p. 240). Schwab's critique that disciplinary organisations of curriculum were constructed under the 'illusion' that they were 'the inevitable products of natural divisions' is certainly the most important insight for this article (1969, p. 241). For more powerful challenges to disciplinary authority, one has to turn to the feminist, multicultural and post-modernist criticisms that followed these reflexive readings (Klein, 1996, pp. 1–15; Messer-Davidow, Shumway & Sylvan, 1993).

Feminists have pointed out the gendered nature of disciplines constructed through values of masculinity and patriarchy. The natural, physical and social science disciplines have been particularly important subjects of this critique. For historians of science like Donna Haraway (1991) and Sandra Harding (1986, 1991), the structured content of the sciences is reflective of the androcentric studies used in its construction. Biology for example, was constructed with a patriarchal underpinning, and much of its disciplinary structure reproduces traditional notions of sex role behaviours. Disciplinary structures in primatology and anthropology are similarly gendered. While one might have learned the structure of the discipline, one was also learning an ideology of western patriarchy and heterosexuality (Klein, 1996).

Multicultural arguments situate the disciplines in their Eurocentric and western cultures. Critics like Henry Louis Gates (1992) and Bell Hooks (1994) point out the disempowering nature of structures in canonised disciplines like English literature and western history. Disciplines are western structures (Hoskin, 1993). These structures were constructed through privilege, and continue to be supported by those with wealth and power. Here, western cultures and disciplinarity are postured as hierarchically superior to cultures marginalized, less advantaged and less concerned with disciplinary knowledge. 'Universalism' of disciplinary structure is a colonial rhetoric (O'Riley, 1996). Western knowledge is rewarded over, and is often antagonistic to, ethnic, racial, multicultural and post-modern understanding. Similarly, gay and lesbian critics point out the heterosexual biases of disciplines in western biology and medicine. Multiple and counter perspectives provide a different and equally valid organisation of knowledge (Delpit, 1992; Klein, 1996; Messer-Davidow, Shumway & Sylvan, 1993).

Post-modern critiques offer a counterpoint to modernist notions that the disciplines are differentiated through separate knowledge bases (Aronowitz, 1991). A post-modern reading of knowledge, *à la* Scott Lash and Donna Haraway, blurs modernist boundaries and rationalities, leaving new configurations of the curriculum in its wake (McLaren, 1993). Here, knowledge is a hybrid of high, counter and popular culture. Disciplinary knowledge is seen as a modernist illusion, and collapses onto a plural landscape in the everyday world. Modernist limits on 'separate' aesthetic, ethical, material, natural, social or theoretical spheres are twisted and reconfigured, encouraging lateral movement and accessibility. In the academy, Cultural, Environmental, Multicultural, Multimedia, Urban and Women's Studies, along with Science and Technology Studies (STS) are enacting this blurring of boundaries (Klein, 1996).

Historical and genealogical studies of disciplines suggest the cultural and social contingency of these artifacts. These studies provide evidence for the arbitrariness of disciplines, and for the forms of power underlying their construction. Boundary-work, or practices of power for separating disciplines from other social forms, is revealed in historico-political perspective. In the work of Michel Foucault, discipline is more verb than noun, where oppression is an ideological function of the disicplines. Disciplines are a means by which a range of actors is brought into knowledge-power relations with each other. Practitioners – human bodies – and knowledge are disciplined. Within these artifacts then, are powerful schemes for dividing and organising the world for action, and for cognition, communication and discipline (Klein, 1996; Messer-Davidow, Shumway & Sylvan, 1993). These artifacts clearly do have politics (Winner, 1980).

Multi- and interdisciplinary challenges to the mono-disciplines

Certainly in the high schools, Science, Technology and Society (school STS), environmental studies, social studies, home economics and art offer, at least conceptually, considerable challenges to disciplinary doctrine. While not post-disciplinary, these fields of study have either configured their curriculum to respond to critiques made since the 1960s, or a long tradition of challenging disciplinary doctrine.

School STS has maintained a lively critique of science education for the past 25 years, and continues to chip away at the status quo in Canada and the US. Its parallel movement in the academy, Science and Technology Studies has been working to generate a sober and democratically robust view of science and technology. School STS has configured curriculum along multidisciplinary and interdisciplinary lines and into a unit organisation. The units are critical issues or problem centred. School STS curriculum has been organised around units such as 'Plague, Pestilence and People', 'Crime and its Impact on Society', and 'DDT in the Environment'. Knowledge crosses disciplines, and draws from non-disciplinary sources as well. But the point of school STS is that the blurring of boundaries and interdisciplinarity is inherent in the curricular organisation itself (Roy & Walker, 1991; Waks, 1991).

Like STS, environmental studies appeared in the 1960s in response to the ecological and social crises of late twentieth century western culture. In both the schools and the academy, environmental studies was situated to break disciplinary boundaries, merging areas like agriculture, ecology, biological and natural sciences, outdoor education, philosophy and technology. It is a multidisciplinary subject. Curriculum has been organised around an environmental problems format, and knowledge oriented toward activism in sustaining responsible and ecologically sound living (Clark, 1989; Gough, A., 1993, 1997; Gough, N., 1993a). And like school STS, environmental studies is facing, in countries like Australia, Canada, England, and the US, the type of opposition that Goodson analysed (1993, pp. 103–166). As Brough concluded: without 'the trappings [of a discipline] this upstart field may continue to be dismissed . . . with these trappings, it risks becoming part of the discipline-bound tradition it is seeking to break' (1992, p. 29). School subjects with longer traditions of challenging disciplinary doctrine have acquired a certain curricular stability, but not without compromise and mixed results.

Social studies, like home economics and industrial education, was constructed in a context of US Progressive Era reform, and a classed, racially and sexually segregated system of education during the late 1800s and early 1900s (Lybarger, 1983). Social studies was constructed at the Hampton Institute as a collective of history, economics, political economy and civics. Hampton was an industrial and trade school for African and Native Americans, with a curriculum focused on manual labour with tools and machines, its dignity, practical knowledge, and 'proper' work attitudes. Hampton social studies involved knowledge of the duties and responsibilities of citizenship, importance of labour and thrift, and the working of social institutions. This ideological function of industrial education and social studies was deemed appropriate by most whites at the time. As advocates of both subjects, neither Booker T. Washington nor Thomas Jesse Jones saw the classical curriculum as relevant to their working class students. It may be that social studies was as oppressive as the classical curriculum in its content and ideological intent, in spite of its anti-academic roots (Eggerz, 1986; Lybarger, 1983).

When social studies was situated in the white, common school curriculum in the 1910s, it was understood in its working class intent, and as a challenge to the classical curriculum. But from this time, the curriculum organisation of this subject has been through either social problems or multiple disciplines (civics, geography, history, etc.). Currently, social studies maintains disciplinary status, partially based on a post 1950s revival of 'integrity' of its separate disciplines. But the subject suffers from an inability to take a multidisciplinary stance with an inclusion of critical content in disciplines such as social psychology and sociology. Geography and history dominate the subject in practice. Status has been at the expense of currency and a critical, robust challenge to disciplinary doctrine.

Home economics in the US has a similar history, and was established for working class girls in common schools as a challenge to the classical curriculum. The subject's most popular proponent in the late 1800s, Ellen Richards, attempted to found the curriculum on domestic science. Other proponents like Marion Talbot attempted to establish home economics as a social study, encompassing problems of family living. Oriented more toward the former vision than the latter in Canada, England and the US, this subject became like industrial education for the boys: a finely divided, skills-based curriculum in manipulating utensils, materials and techniques with a pre-vocational end. Where boys in industrial education were destined for work outside the home, the young girls in home economics were destined for work inside the home (Apple, 1994; Attar, 1990; Brown, 1985a, 1985b; Powers, 1992; Rury, 1988).

At the same time that industrial educators were reviving disciplinary rhetoric, home economists were reviving critical, feminist, and reconstructionist discourses rooted in their past. Without disciplinary delusions, Marjorie Brown, in the late 1970s, had organised the curriculum as a multidisciplinary endeavour based on practical problems, and cast within a framework of critical theory (Brown, 1978, 1985a; Grundy & Henry, 1995). In Canada during the mid 1980s, Patricia Thompson had begun to resituate home economics squarely within a feminist 'Hestian' tradition of separate spheres (Thompson, 1988, 1992). In the late 1980s, the American Home Economics Association (AHEA) had adopted Brown's ideas, and a critical, multi- and interdisciplinary curriculum (AHEA, 1989). Conceptual domains of the curriculum include: Consumer and Resource Management, Housing and Living Environments, Individual, Child, and Family Development, Nutrition and Food, and Textiles and Clothing. A practical problem could be 'what to do about a childbearing decision in the face of limited financial resources?' (Hultgren & Wilkosz, 1986, p. 143). Practice in home economics continues to be rooted in problems of everyday life, consistent with traditions; however these problems are currently cast within larger contexts and studies. With its end in an activist's, and feminist's, 'Improvement Of Human Life In The Home And Family', the curriculum offers a refreshing, conceptual challenge to a conservative, disciplinary doctrine in the US and Canada (Brown, 1978, p. 27; Peterat, 1995).

Drawing outside the disciplinary lines with multidisciplinary colours

Art in the schools, like technology, is experientially centred. The design, production and use of cultural artefacts *via* a manipulation of materials and tools remains a basic method for engaging students with socio-cultural issues of art. In fact many techniques, tools and materials used in the art studio are those found in the technology laboratory and workshop. Like technology, an emphasis on productive activity in art had/has compromised student growth, and the critical meaning of the subject in general education and civil society.

Art education in the US and Canada offers a striking similarity to technology education in terms of current status, epistemology, and a shared past. Art's current status in the schools today is like that of the status of technology education. In the secondary curriculum, art is an elective, usually chosen by a minority of the student population. In British Columbia (BC) schools, some art courses can count as 'applied skills' course, while certain technology courses qualify as 'fine arts'. School departments have sometimes combined art and technology, under a 'practical arts' title. In BC's primary schools, art is often valued as a method for exploration and integration. Recent initiatives in Design and Technology in Australia, England and Wales blur boundaries that were first used to separate the subjects during the 1800s.

In a context of industrial capitalism in 18th and 19th century Britain, North America and Europe, a classed system of work was formed. This division of labour had challenged the traditional relations and practices of the workshop system, severing artistic from manual activities. Design had been separated from production. The separation was played out in a distinction between the fine and applied, industrial, or manual arts. Art had become distinguished from craft, or fine from decorative and ornamental arts. The fine arts were represented in painting and sculpture; the applied arts in activities like in drawing, design, mechanics, and printing. The practice of fine arts was held as superior to that of the applied, and was a matter of greater dignity, especially in North America. Artistic labour was held superior to industrial or manual labour. These historic processes merely reproduced and reinforced a long-standing separation of the servile from the liberal arts (Efland, 1990, pp. 49–72; Mumford, 1952; Panyotidis, 1996).

Art education was introduced into common schools primarily for its utilitarian purposes, and only secondarily for aesthetic reasons in countries such as Canada, England, Germany, and the US. Drawing, in its mechanical, skill-based form, was seen to be essential to a general working class literacy, for workers and workers' children alike (Efland, 1990, pp. 92–114, 130–142; Korzenick, 1985; Stevens, 1995, pp. 37–49). If an aesthetic sense of the world and refinement was learned by working class students, all the better. Art, as practical drawing, became a subject in manual training schools of the late 1880s as well as the grammar schools.

In BC, drawing was introduced into the upper primary grades and secondary schools for working class students during the early 1900s. It wasn't until the 1920s that manipulative activities like clay and Plasticine modelling, as well as paper folding, were introduced as a lower primary grade subject, called manual arts (Rogers, 1984, pp. 81–104; 1987, p. 248). Art and manual training were one, albeit with different instructors and viewed as a compromise for art, in the working class stream. The manual training and industrial arts director in BC from 1913 to 1938, John Kyle, was himself an artist with fine arts training, and Art Master at the Provincial Normal School in Vancouver during the 1910s (Rogers, 1987, pp. 170–171). Kyle tried to walk the thin line between an increasing vocationalisation of industrial arts, and his own debt to art and design. Art, like technology, has a history of struggle for status in the school curriculum.

Art and technology education share debts to the common school, Arts and Crafts, Bauhaus, and social meliorist movements of the late 1800s. People such as Jane Addams, Friedrich Froebel, Maria Montessori, Johann Pestalozzi and Jean Jaques Rousseau dealt with art *and* technology in education (Efland, 1990). In overcoming a historic separation, art and technology were fused in John Ruskin's and William Morris' Arts and Crafts movement, the Bauhaus, and in the educational practice of John Dewey (Amburgy & Soucy, 1989; Efland, 1990, pp. 133–142, 191–210, 214–219; Panayotidis, 1996; Stankiewicz, 1984). Morris, through the Arts and Crafts Movement of the 1880s and 1890s, had *rejected* the modern factory for its degradation of labor and its manufactured product, and addressed the decorative arts as a fusion of art and technology. Walter Gropius, within the Bauhaus during the 1920s, unified art and technology in design *for* the modern factory and mass produced objects. Art and technology came together in a number of ways in Dewey's work, and his notions of experience underwrite shop *and* studio practice in schools today (Eisner, 1972, pp. 29–63; Soucy & Stankiewicz, 1990). In *Art as Experience*, Dewey placed art and technology on the plane of experience, and argued for the value of an aesthetic sense in both social practices (1934, pp. 35–58). Nonetheless, divergences in the schools during the 20th century left technology to romance vocational education and industry, while art was left with both feet planted firmly in general education. Technology became a 'masculine' subject popularised by male teachers; art became a 'feminine' subject popularised by female teachers. From an historical perspective, reasons for taking a close, contemporary look at curriculum in art seem considerable.

Discipline-based art education

In the same context of the early 1960s that shaped the technology discipline, Manuel Barkan cast art education in a disciplinary form. Like DeVore and the IACP directors, Barkan viewed the art curriculum's dominance of studio practice, or art making, as a liability in status. But unlike those concerned with technology, Barkan chose an unorthodox route, one that was multidisciplinary, for providing art with a structure. Barkan suggested that art 'criticism', art 'history' and art 'studio' or 'production' constituted the disciplines for knowledge in art education. If Barkan had been concerned with the equivalent of the first taxonomic move in the technology discipline, art would have been structurally cast in mono-disciplinary 'areas' of architecture, dance, design, drama, literature, music, and visual art. Visual art would have been divided into drawing, painting, photography and film, and sculpture, and each of these sub-divided, and so on. Instead, art had been set on a 'discipline-derived' or multidisciplinary course, somewhat similar to social studies (Efland, 1987, 1988, 1990, pp. 240–254).

In the early 1980s, when technology educators were reviving disciplines of the 1960s, art educators associated with the J. Paul Getty Trust's Center for Education in the Arts renewed disciplinary interests in art. In 1984, the Getty Center published *Beyond Creating: The Place for Art in America's Schools*, and staff director Dwaine Greer published his article 'Discipline-Based Art Education' (DBAE) (Greer, 1984). A name had been given to a series of initiatives beginning in the 1960s, and 'aesthetics' was proposed as a fourth discipline in art. With the Getty Center's financial support and cultural capital, and advocates like Elliot Eisner, DBAE became a popular curriculum for art educators in Canada and the US. In both countries, DBAE became the *de facto* curriculum in varying degrees and practices for schools and teacher education faculties. Although less likely to acknowledge the term 'DBAE', England's curriculum is also discipline-based, with art perception substituting for aesthetics.

A key point is that art educators have evidently been able to balance an experiential curriculum with critical and social inquiry, within a multidisciplinary framework. Production is balanced with equally important understandings of cultural, historical and social practices in art. Production rules the day only in that this practice discloses and informs an aesthetic, critical and historical content.

The four disciplines are theoretically enacted in a complementary and porous fashion. *Aesthetics* serves as a source for philosophical understandings of art (Clark, Day & Greer, 1987; Eisner, 1987; Greer, 1987). Students learn to discern differences in works of art, and to make judgements based on aesthetic concepts (harmony, rhythm, etc.), artist intent and cultural notions of meaning, quality or value. Reflection is given to aesthetic experiences with art, and the nature of a 'work of art'. Generally, aesthetics is a source for knowledge about personal feelings regarding an experience with art, the meaning and quality of works of art, and criteria for appreciation and judgement. *Art criticism*, like aesthetics, is a source of knowledge for developing perception and discernment with regard to art. It deals with the cultural tools for perceiving meaning, and for discerning the trivial from the meaningful in art. Students learn to focus on a particular art piece, and place the work within its cultural and social contexts. Generally, art criticism helps students develop a mode for understanding sign and symbolism, and discussing art in the context of style and cultural meaning. Aesthetic 'scanning' is typically interwoven with art criticism. *Art history* provides students with knowledge and a sense of the interaction of art and culture over time. Students learn to temper their aesthetic and critical judgement of art with cultural and temporal sensitivity. *Art studio* or *production* deals with the direct experience of creating art. Students develop expressive abilities, artistic technique, originality and skills, as production discloses insight into their own potential as well as the media and context with which they work. There are varied interpretations of these disciplines, and schools of thought on how DBAE works, or how DBAE ought to work in practice (e.g., Kindler, 1992; Wilson, 1997).

Of course, DBAE was not shaped and introduced in schools without criticisms, discontents and resistance. Among the general critiques of the disciplines noted earlier, there are those particularly attuned to art education discourses (Hamblen, 1988; Irwin & Reynolds, 1995). A nagging reaction is that DBAE in practice requires that time be taken from art production for other pursuits. Hence, students' artistic development suffers for the sake of cultural understanding. With a move from art production and its therapeutic traditions in schools, DBAE may defeminise art (Collins, 1995). It has also been argued that overlap among the four disciplines contributes to confusions in theory and practice. For example, aesthetics is confused with criticism in that both deal with discernment of art and technique. Inasmuch as DBAE has been positioned within traditional notions of aesthetics and criticism, it has been a modern, western enterprise. With its canonisation of certain historical works of art, DBAE affirmed modern, western values. Without a multicultural outlook in and among its four disciplines, DBAE stood to reproduce an Anglo-oriented, heterosexual, white male, classed and élitist, cultural canon. Without interrogating socio-historical separations between 'high' and 'popular' culture, or between fine arts and craft, DBAE affirmed upper and middle class worldviews. DBAE's reification of an 'expertise' in the practices of professional artists, critics, and historians reinforces a troubled model, reducing views of art held by a non-expert, general polity to uninformed 'opinion'. The student is no longer 'already and becoming' an artist. And by setting up a model of the citizen *qua* sophisticated artist, art surrenders an effort at democratisation of a sometimes élitist social practice (Collins, 1995; Jagodzinski, 1997; Swift, 1993; Wolcott, 1996). Proponents of DBAE have taken steps to address at least some of these criticisms, and have reflexively reshaped their enterprise for the 1990s (Chalmers, 1987; Chalmers, 1996).

As Multidisciplinary Technology Education (MTE) was developed, it was unnecessary to walk DBAE's multidisciplinary path step for step. With the advantage of hindsight into DBAE and reflexion, certain discontents and historic troubles were kept conscious as MTE was constructed. For example, where DBAE was, and to a degree *is*, bound up with the conservative cultural literacy ideas resurrected in the mid 1980s, there was no good reason to re-enter this discourse with MTE. And where whiggish histories of great works were invested somewhat in DBAE during the 1970s and 1980s, more contemporary notions of history informed MTE. The history of art seems to be privileged at the exclusion of media and semiotic studies, feminist studies, or studies in the politics or sociology of art. Notions of criticism in art and technology differ on a point. Art criticism tends to be a practice oriented toward reacting to the production of art, while questioning the inherent values of certain artwork and practices. Criticism of technology is oriented toward shaping design, production and use, while questioning the inherent values of certain technologies and practices.

I have no delusions of structural universalism, nor am I fond of disciplinary rhetoric adopted by educators, including those in art. It does not matter whether art studio, aesthetics, or art criticism are 'disciplines' with modes of inquiry, or mere social practices and areas of study. This is a subject for uninteresting debate. MTE could well have been 'Cross-disciplinary Technology Education' (CTE). My purpose here is political: To introduce a counter and plural discipline, or multidiscipline, for the school subject of technology. There happens to be a persuasive, defensible rationale for making this move along the path found by art educators. Indeed, there are good reasons for appropriating a general design from art for technology; or for looking to artists to inform technology. I have no reservations about appropriating the 'good(s)' from artists and educators! This is merely the political 'first step'; grassroots and network politics will eventually follow.

MULTIDISCIPLINARY TECHNOLOGY EDUCATION (MTE)

> The principal problem facing the curriculum designer who adopts the disciplinary perspective is not how to distinguish *between* disciplines; it is how to *select* which versions of which disciplines to impart at a time when not only the number but also the number of *versions* of extant disciplines is constantly expanding (Schrag, 1992, p. 287).

The focus of MTE is technology balanced across four interdisciplines in education. The 'interdisciplines' of technology are: technological 'practice', 'design', technology 'studies' and 'criticism' of technology. These are the *primary* sources of knowledge for technology as a school subject. Concepts, ideas, principles and techniques that guide MTE reflect the four interdisciplines from which they are selected. Technical-empirical, socio-political, and ethical-personal dimensions of technology are balanced through explicit attention to these interdisciplines.

Technological practice deals with the manipulation of information, tools, machines and materials for the design, production and use of artefacts and techniques. Artefacts and techniques may have artistic, utilitarian, or combined ends, through either custom or batch production. Laboratory, workshop or field-based practice involves formal and tacit knowledge in endeavours like design and production, invention and development, programming and testing, modelling and troubleshooting, etc. Care, cognitive and physical skill, and self-confidence are enhanced through the use of traditional materials, hand tools and new technologies. Practice has a methodological aspect in the schools as a well as a practical aspect. The technologies used and produced by students are selected for their disclosive, as well as expressive, power. In technological practice, artistic, mathematical, or scientific principles are disclosed through selected problems and projects. The operative nature of selected instruments or disassembly techniques discloses properties of materials, parts and processes. And carefully chosen, certain technologies in use disclose insight into conditions of home, farm, or factory work, or into social conditions regarding ecology, gender, or race. Technological practice is positioned in its unrestricted sense, where technical-empirical work is understood only in regard to its socio-political and ethical-personal dimensions. In MTE terms, practice makes sense only in relation to design, studies and criticism (Mitcham, 1994, pp. 209–246; Pacey, 1983, pp. 1–12).

Design is both a mode or model of technological practice, and an interdiscipline. Design is a source of philosophical and practical knowledge regarding problems of aesthetics, ergonomics, health, function, structural integrity, and sustainability. It provides guidelines for successful construction or deconstruction, as well as criteria for discerning intent and quality, or the 'workable' and 'non-workable,' in technology. Design organises knowledge embedded in cultural tools such as engineering tables, drawings and models, heuristic strategies, efficiency calculations, reliability, recyclability and safety ratings, and user surveys attuned to physical or sexual differences. Of course a unified notion of design does not exist, and as a rule, the more concrete the idea for an artefact, image or process, the more direct design knowledge becomes. Perhaps the Bauhaus came closest to connecting architectural, engineering, fashion, graphic, interior, product and urban design within a single fund of knowledge and style. Today, engineering design is generally a source of structural and material knowledge, while disciplines like architectural and product design are sources of aesthetic and ergonomic knowledge. Biotechnical and therapeutic design are sources of knowledge concerning agri- or aquaculture, health and medicine. Philosophies like appropriate or intermediate technology, user-centred design, integrated and participatory design, concurrent engineering, and product life cycle represent tangible visions for transforming the immediate ground of technological design (Buchanan & Margolin, 1995; Hubka & Eder, 1995; Johnson, 1977, pp. 5–34; Mitchell, 1993; Norman, 1988; Pahl & Beitz, 1996; Pugh, 1991; Young & Vanderburg, 1992).

Technology studies is a lively interdiscipline that includes the anthropology, economics, history, philosophy, politics, semiotics, social psychology and sociology of technology and technoscience. Over the past two decades, this interdiscipline has challenged traditional understandings of technology, and has been working to undermine problematic technological practices in Australia, Britain, Europe and North America. Spanning contextual, socio-historical understandings with a critical knowledge of current and projected technologies, technology studies deals analytically with human interactions with technology. For example, technology studies informs empirical questions of interrelations between science, technology and capitalism, or between human agency and social process in the development of new technologies. This interdiscipline also deals historically and conceptually with issues such as technological threats to labour or privacy, and class, gender and race issues related to technology. Technology studies encompasses political knowledge concerning constructive technology assessment, and other social practices aimed at managing technological change. With this knowledge are the tools and discourses for empirically investigating and theorising, and in turn making decisions about, technology or technoscience (Bijker, 1995; Goldman, 1989; Grint & Gill, 1995; Hess, 1992; Jasanoff et al., 1995; Jellison, 1993; Latour, 1987; Lowe & Krahn, 1993; Margolin & Buchanan, 1996; Mitcham, 1994; Norman, 1988; Petrina, 1990; Rip et al., 1995; Sclove, 1995; Volk, 1990; Wajcman, 1993).

Criticism of technology extends from ‘internal’ design criteria to social philosophies of technology dealing with values embedded in technological practices and their contexts. It deals with ethics, regulation, responsibilities, and our relations with technology and technoscience. While design and technology studies maintain a critical content, criticism is an interdiscipline concerned mainly with the social evaluation and monitoring of technological design and practice. Criticism links studies of technology with strategies and visions for improving the design and practice of technology within sustainable contexts. The critic of technology asks fundamental questions about what a technology offers (perception and description), what it means with its embedded values (analysis and interpretation), and the technology's worth (judgement). Criticism bridges tools from design for internal evaluations such as efficiency or ergonomics, with social criteria regarding the technologies' characteristic framings of ecology, equity or quality of life. This is not an *anti-technology* stance, but a fund of knowledge toward public understanding, regulation, and sensibility. This interdiscipline encourages a critical attitude toward questioning technocratic assumptions, and technologies' interaction with notions of autonomy, determinism, and progress (Petrina, 1992). Questioning acknowledges the voice of those marginalized by western styles of technological practice, such as aboriginal peoples, the financially disenfranchised, feminists and ecologists (Drengson, 1995; Deleuze & Guattari, 1987; Durbin, 1992; Ezrahi et al., 1993; Goldman, 1989; Haraway, 1991; Mander, 1991; Mitcham, 1994, pp. 267–294; Rothenberg, 1993; Smith & Marx, 1994; Waks, 1992; Weisman, 1992; Winner, 1980; Wood, 1997).

Teaching within MTE aims to help students develop skills of expression and utility, *and* attend to technology, in its broad human and social context. This requires balance and a commitment to help students reflect within a curriculum that has a history, like art, of overemphasising 'making and doing'. One assumption is that technical practice can, *if* enacted contextually, empower students to develop confidence with tools, and demystify the technologies with which they work. A second assumption is that gradually, through middle school and beyond, our relationship to technologies can become critical, interpretive, and weary of oppressive characteristics. MTE recognises value in each of the interdisciplines described above.

For example, Computer Aided Design (CAD) in a MTE secondary curriculum is contextualized as students gain an understanding of its use in technological practice. The technical skills of using CAD for modelling are balanced with understandings of sociotechnical aspects of these technologies in the design processes of various workplaces. The senior students engage with questions related to managerial expectations and strategies for CAD, organisational cultures for innovation with CAD, job designs and task allocations for CAD users, and changes in engineers', fashion designers' or physical therapists' job content. These students develop the tools for critically evaluating CAD with regard to automation, or this technology's use as a 'Trojan horse' for the Taylorisation of mental work in design. Students have the capacity to appreciate and use CAD, while evaluating the discourses surrounding CAD's use (Downey, 1992, 1995; Downey & Lucena, 1995; Majchrzak & Salzman, 1989).

For a student enrolled in MTE at the junior secondary level, a unit on bicycles is an example. This student learns basic repair techniques, and the systematic workings of bicycle parts. She is challenged to design particular accessories, paths, or parts while attending to problems of aesthetics, ecology, ergonomics, force, gear ratios, material characteristics, mechanical

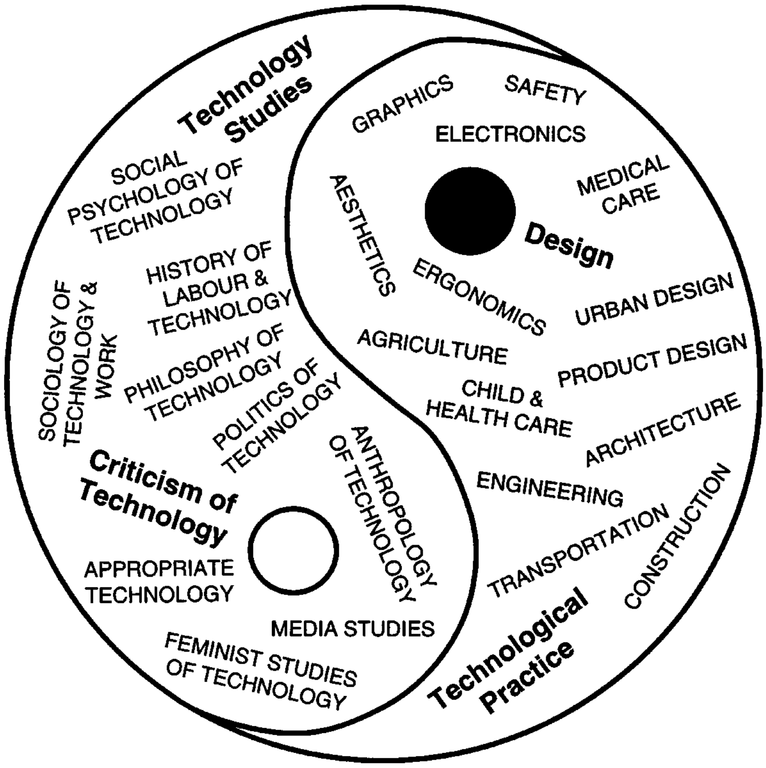

Figure 3. MTE supports an explicit balance across technical-empirical, socio-political, and ethical-personal dimensions through four interdisciplines. The yin/yang of Chinese philosophy is not only symbolic of balance, but also of continuous cyclical movement. There is continuous transaction across the interdisciplines, criticism, design, practice and studies, which are suggestively demarcated in this figure.

advantage, and safety. An international perspective on bicycle use in a larger context of appropriate technology, energy consumption and transportation policy accompanies her technical knowledge. She begins to understand the social construction of a mountain bike for instance, and critically evaluates this technology's symbolic content relating to gender or wilderness (Bijker, 1995; Lowe, 1989; Rosen, 1993) (Figure 3).

MTE does not require a complete renovation of existing practice in the schools, inasmuch as a recognition of the richness in a balance of content and resources. Teachers assume responsibilities for a critical selection of the technologies used in the field, laboratories and workshops. Selection is evaluated against the technologies' disclosive power to inform critical and social questions. Teachers work toward critical and sociotechnical understandings of the technologies they select. Epsitemologically, learning cycles in MTE begin with the disciplines of practice and design, and extend toward disciplines of studies and criticism (Petrina, 1997c). Units with teachers in subjects such as art, chemistry, home economics, language arts, math, physics or social studies are sometimes co-ordinated. Units with case study focuses are among the best forms for actualising knowledge in MTE. In summary, MTE is a curriculum for critical pedagogy.

ORGANISING KNOWLEDGE IN MULTIDISCIPLINARY TECHNOLOGY EDUCATION

By definition, MTE positions technology as a multidisciplinary school subject concerning knowledge in designing, creating, using, maintaining, managing, regulating, and recycling products, processes and services. This includes a concern for deliberately balancing in curriculum the technical-empirical dimensions of technology, or technique, with its socio-political and ethical-personal dimensions. MTE positions technology, like DBAE for art, as multidisciplinary in outlook. The curriculum works to demystify technology and provide a rounded range of critical, cultural, social and technical skills. MTE is intended to provide a critical, political regard for decision-making in industry, labour, work and technology, as much as an aesthetic and ecological regard for humanity and life. MTE places a primary value on experience and encourages development for participation – from 'practical' to political – in all facets of technological endeavour. The subject has its end in the development of participation, technological sensibility and political sagacity. This is similar to Pretzer's (1997) notion of technological integrity.

Participation – act or fact of sharing or partaking (McKechnie, 1983, p. 1306).

Sensibility – the capacity to respond intelligently and perceptively to intellectual, moral or aesthetic events or values; delicate, sensitive awareness or responsiveness; intellectual perception (McKechnie, 1983, p. 1652).

Sagacity – quickness or acuteness of discernment or penetration and soundness of judgement; penetrating intelligence (McKechnie, 1983, p. 1596).

MTE, like art or environmental education, positions technology as a school subject and at the same time a social movement. The mission of technology education is to provide experiences for young people to develop and question knowledge and skills that empower them to participate in all facets of technological endeavour – from the 'practical' to the political. The mission of technology education means constructing and sustaining a social vision for inclusiveness, ecological sensitivity and justice for the common good in work and leisure. It means sustaining a vision for transforming personal and social interactions with technology into democratic initiative. It is a mission for social responsibility, enacted through ends of participation, technological sensibility and political sagacity. In the end view is an adult with a complex, political understanding of technology, participating in a democratic, peaceful, sustainable society (Petrina, 1995).

A hard lesson to be learned is that the way we organise practical knowledge, the technologies we select to teach and our *relationship* to these technologies are academic *and* political matters. It matters that we organise technological practice in its relations to criticism and studies. It matters that we critically select technologies for their power to disclose insights into aesthetic, cultural and social life. Technological practice can be used to disclose realities of class, labour, ecology, gender and race (Petrina, 1997c). These matters require a turn *from* our past and an ideology of technological progress and mono-disciplines. It matters that the end of technology education be renegotiated away from capitalist economies and realigned with a vision of ecology, freedom, justice and labour for a better world. Realignment would entail a turn *toward* our critical past and stark realities of social progress (Petrina, 1995).

Organising knowledge in MTE

Knowledge is organised through questions and inquiry within the interdisciplines of MTE: practice, design, studies and criticism. MTE begins with what is often an innocent query of children and adults: 'How can I make this?' But, MTE recognises that innocent questions in technology are in fact 'loaded'. The framing, loaded questions are intended to reflect an ascending order of complexity, but also retain their innocence throughout. Innocent questions can be answered innocently, and often are for children, and rightly so. But, an innocent answer to a loaded question for young adults in education may in fact be a sign of a lack of depth in the understanding of an answer or its context. Students and their relations with technology are too important for shallow initiative and thought.

Knowledge in MTE is also organised on concepts which inform the loaded questions. Each concept refers to both understanding and use. The organisation places concepts, within and across questions, in ascending order. Levels of concepts are NOT mutually exclusive, and those listed are NOT all-inclusive. But they are those that would be basic to a MTE curriculum sequentially organised beginning from kindergarten and extending through adulthood. Levels of understanding would develop progressively. For neither children or adults should the end of the curriculum fall within the first group of questions and concepts. As indicated, the stakes are too important for a trivial treatment. Eventually through sustained questioning, practice and study, students will develop more meaningful and complex understandings of technology, and toward the valued end of the curriculum – technological sensibility and political sagacity through adulthood.

The following outline represents an organisation of knowledge in MTE, which is provided for a comparison with that of the mono-disciplines of technology. The organisation is not solely technical, as it has been in the tradition of mono-disciplines. The progression built into the outline reflects that of practice *across* four interdisciplines in MTE (Petrina, 1997c). Here, the organisation of knowledge is inter- and transdisciplinary.

How can I do or make this? How was this made or done? How can I take this apart? What does this do, how does this work and how do I use it? How can I design this? How can this be fixed, maintained or improved?

- Design (architectural, biomedical, engineering, graphic, interior, product, urban) – Principles and theory of aesthetics and function; Standards; Ideation, drawing, modelling and presentation; Experimentation and Testing; Order and planning; Cost estimate and comparison; Customisation; Reverse Engineering; User-centred design; Integrated and comprehensive anticipatory design; Concurrent engineering; Product life cycle.
- Materials, Energy, Process and Structure – Allocation, (re)manipulation, (re)utilisation and limitation; Natural resources and synthetics; Generation and transformation of power; Physical, structural and aesthetic properties; Morphology; Waste reduction and removal; Media of expression; Dynamics and Statics.
- Tools and Utensils, Instruments and Machines – Use, efficiency and technique; Care and maintenance; Configuration and operational principles; Power and control; Quality control; Testing and Troubleshooting; Safety.
- Human Factors or Ergonomics – Manual, mechanical and automated or cybernetic systems; Feedback; Affordance, constraint and mapping; Human-machine-artefact interface and symbiosis; Information and artificial intelligence; Reverse engineering; Cyborg and prosthetics.

What and who was/is this for? Was/is this novel or necessary, and safe? What and whose resources were/are used to make this? What was/is the motive for making this?

- Subsistence, Art and Utility – Survival; Luxury; Novelty; Fashion, style and taste; Minimalism; Subjectivism; Relativism; Expression and poetic license; Aesthetic and Utilitarian Judgement.
- Consumerism – Consumer law and protection; Investigative media; Planned obsolescence; Marketing and hype; Human engineering; Manipulation of choice and need; Adulteration; Commodity.
- Ecology – Perma-Culture; Industrial ecology; Conservation, development, scarcity, sustainability and waste; Accumulation; Pollution; Bioregionalism; Preservation and Restoration; Green republic.
- Consumption, Convenience, Capitalism and Commercialism – (Dis)information, product and labour markets; Price fixing and fluctuation; Enterprise and competition; Industrialism and urbanism.
- Desire; Cultural Values and Identity – Symbolism; Semiotics, language and semantics; Static and Dynamic Quality.

Who made this? How was labour and work organised to make this? What were the conditions under which this was made?

- Artisan Knowledge, Handicraft and Skill – Specialisation; Standardisation.

- Occupations and Conditions of Labour – Labour market; Job content and design; Skills and training; Economic sectors; Occupational health and safety; Discrimination and harassment; Power; Workers' rights.
- Organisation of Labour, Technology and Work – Division of labour; Sexual division of labour; Home, factory, office, sweatshop and open-air; Entrepreneurism; Batch and mass production; Interchangeable parts; Assembly line, mechanisation and automation.
- Management and Unionism – Bureaucratic structure; Scientific management; Time, motion and fatigue; Total Quality; Participatory management; Labour relations.
- Industry and Labour – Distribution of work and income; Centralisation; Productivity; Capital; Alienation of work; Exploitation and imperialism; Colonialism.

What was used before this? Who developed and who used this? What happened?

- Technological Change – Technological evolution and cumulative change; Invention, development, innovation, diffusion; Social construction of technology; Social and cultural selection; Technoscience.
- Historical Continuity and Social Change – Serialisation; Anecdote; Human agency and intentionality; Contingencies; Technological determinism; Autonomous technology; Dialectical materialism.
- Interaction of Technology, Culture and Society – Interdependence of Science and Technology; Technological system; Research laboratories; R&D; Actant-theory network.
- Industrial, Military, University Complex.
- Interaction of Technology, Class, Gender and Race.

Is there a better way of making, using and working? What are the options?

- Praxiology and Mechanology – Economisation of energy, time, materials, terrain and apparatus; Precision; Efficiency; Functionality; Durability; Speed; Skill; Ingenuity; Method; Working plans; Engineering Sciences (Statics and Dynamics).
- Technophilosophy – Functionalism; Technocracy; Biomorphic and organic design; Bauhaus, Dymaxion (Buckminster Fuller) and Usonian (Frank Lloyd Wright).
- Forecasting and Assessment – Input/output; Cost-benefit; Systems analysis; Trend extrapolation; Dynamic modelling; Hazard; Higher order consequence; Technological forecasting; Risk assessment; Constructive technology assessment.
- Appropriate or Intermediate technology – Polytechnics and monotechnics; Anatechnology and catatechnology; Local knowledge; Decentralisation; Technology transfer.
- Philosophies and Theories of Work and Technology – Workplace democracy and profit sharing; Technology Bill of Rights; Technological 'progress'; Bauhaus; Neo-Luddism; Feminist technology; Democratic

and autocratic technology; Civilising, democratising or humanising technology; Constructive technology assessment; Marxist analyses; Material semiotics; Distributive justice and wealth.

What will help me to change how things are made and used, and who participates in technology?

- Critical Regard and Activism – Gender studies; How things work; Do-it-yourself; Access to information; Community Initiative; Act locally – think globally.
- Feminist and multicultural critiques of technology.
- Collective, Democratic, Grass Roots and Regulatory Action – Science, Technology and Workplace Policy; Environmental and social policy; Investigative initiative and media.
- Quality of Life – Human rights; Dignity of work.

Where do I begin with my lifestyle?

- Simplicity, Modesty and Frugality.
- Prudence and Sensibility, Dignity and Compassion.
- Vision – (Re)enchantment of nature and technology.
- Artistic Expression and Political Statement.
- Activism – Ethical Standards and Moral Strength.

Conclusion

> Students and their teachers, researchers and scholars, workers and citizens live in a world in which problems require both specialized skills and the integrative skills to cope with complexity. They live at a time when a general weakening of all cultural boundaries is flattening hierarchies, blurring categories, and rendering organizational lines ambiguous. . . . It has been occurring for nearly a century in the form of interdisciplinary activities that recontextualize disciplines, weaken boundaries, and alter identities (Klein, 1996, p. 237).

The trajectory of this argument has split disciplinary doctrine along critical faults, and meandered along a path through mono-, multi- and interdisciplinary terrain. The mono-disciplinary route for technology was found to be an over-developed and worn cul-de-sac, looping the trail back into itself. That is the direction toward which disciplinary doctrine points. Skipping along the path found by art educators, it appears that a less travelled but orienteered, multidisciplinary route would be the most democratically fruitful to travel in the 1990s. Instead of the mono-discipline path, as disciples in the US have been wont to travel since the 1960s, I proposed a path of a multidiscipline: MTE.

Accepting neither capability nor literacy as meaningful ends for a study of technology, MTE is a path toward technological sensibility and political sagacity. Technological capability can be tightly linked to the needs of the state, as has been the case with Thatcher's politics in England, and similar economic policies in the US (Lewis, in press). Capability is an end that positions technology education within the capitalist economy which pits country against country in a zero-sum contest. Technological literacy has been conceived as complimentary to capability, and in turn, is aligned with these economic interests. In practice, literacy serves as a referrent to *whatever* is taught. To be sure, a realignment with art through MTE can be viewed as a move from the rhetoric of the state and economic control of technology education toward a rhetoric of the public and democratic control. This path also rejects distinctions between 'academic' and 'vocational' education, redefining each to subsume the other. MTE values practical knowledge in technology and work, as well as academic knowledge surrounding these endeavours.

MTE contradicts any misnomer that practice and design can be done outside of a context of studies and criticism. In this regard, technical-empirical, socio-political, and ethical-personal dimensions of technology are explicitly balanced and meaningful for curriculum organisation. Issues regarding class, gender and race are problematised for research and serve as content in criticism, design, and studies. By naming technology studies and criticism as primary interdisciplines, MTE offers a middle path between Australian and British ideas of process-based D&T and the American ideas of mono-disciplinary content. D&T and the mono-discipline merely gesture toward 'possible' roles for studies and criticism; MTE makes these essential.

MTE is conceptually and intentionally conscious of critical, working class conditions and traditions in the history of technology education. It is intended to be intuitive, but counter to the conservative, mono-discipline that has been developed in the US over the past 35 years. The path here is entirely open toward a critical engagement with the issues discussed, and a reflexive turn toward its political ecology. In time, MTE may give way to a post-disciplinary curriculum, as mono-disciplinary practice becomes the exception, *not* the norm. For now, it will pay to maintain a cautious stance toward my contentions, while entertaining the content of possibilities in MTE.

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THE AUTHOR

Dr. Stephen Petrina is Assistant Professor of Technology Studies Education in the Curriculum Studies department at the University of British Columbia. He has written on critical pedagogy and the politics of curriculum in technology studies, and the cultural constraints of teaching and learning about technology. He is working on a social history of industrial education, 1870s–1950s (US and Canada). His research interests also extend to workplace studies, concerning the cultural situation of computer aided design. Most recently, he has focused on a ‘Science and Technology Studies’ approach to understanding the rise of psychological technique as epistemological practice in education, and the interrelationships between medical, psychological and educational cultures.