Chapter 21

Politicizing Mathematics Education:
Has Politics gone too far? Or not far enough?

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In this chapter we tackle increasingly sensitive questions in mathematics and mathematics education, particularly those that have polarized the community into distinct schools of thought as well as impacted reform efforts. We attempt to address the following questions:

- What are the origins of politics in mathematics education, with the progressive educational movement of Dewey as a starting point?
- How can critical mathematics education improve the democratization of society?
- What role, if any, does politics play in mathematics education, in relation to assessment, research and curricular reform?
- How is the politicization of mathematics education linked to policy on equity, equal access and social justice?
- Is the politicization of research beneficial or damaging to the field?
- Does the philosophy of mathematics (education) influence the political orientation of policy makers, researchers, teachers and other stake holders?
- What role does technology play in pushing society into adopting particular views on teaching and learning and mathematics education in general?

- What does the future bear for mathematics as a field, when viewed through the lens of equity and culture?

Overview

Mathematics education as a field of inquiry has a long history of intertwinement with psychology. In fact one of its early identities was as a happy marriage between mathematics (specific content) and psychology (cognition, learning, and pedagogy). However the field has not only grown rapidly in the last three decades but has also been heavily influenced and shaped by the social, cultural and political dimensions of education, thinking and learning. To some, these developments are a source of discomfort because they force one to re-examine the fundamental nature and purpose of mathematics education in relation to society. The social, cultural and political nature of mathematics education is important for a number of reasons:

- Why do school mathematics and the curricula repeatedly fail minorities and first peoples in numerous parts of world?
- Why is mathematics viewed as an irrelevant and insignificant school subject by some disadvantaged inner city youth?
- Why do reform efforts in mathematics curricula repeatedly fail in schools?
- Why are minorities and women under-represented in mathematics and science related fields? Why is mathematics education the target of so much political/policy attention?

The traditional knowledge of cultures that have managed to adapt, survive and even thrive in the harshest of environments (e.g., Inuits in Alaska/Nunavut; Aboriginals in Australia, etc) are today sought by environmental biologists and ecologists. The historical fact that numerous cultures successfully transmitted traditional knowledge to new generations suggests that teaching and learning were an integral part of these societies, yet these learners today do not succeed in the school and examination system. If these cultures seem distant, we can examine our own backyards, in the underachievement of African- Americans, Latino, Native American and socio-economically disadvantaged groups in mathematics and science[1](Sriraman, 2008). It is easy to blame these failures on the inadequacy of teachers, neglectful parents or the school system itself, and rationalize school advantage to successful/dominant socio-economic groups by appealing to concepts like special education programs, equity and meritocracy (see Brantlinger, 2003).

In the second edition of the *Handbook of Educational Psychology*, Calfee (2006) called for a broadening of horizons for future generations of educational psychologists with a wider exposure to theories and methodologies, instead of the traditional approach of introducing researchers to narrow theories that jive with specialized quantitative (experimental) methodologies that restrict communication among researchers within the field. Calfee (2006) also concluded the chapter with a remark that is applicable to mathematics education:

> Barriers to fundamental change appear substantial, but the potential is intriguing. Technology brings the sparkle of innovation and opportunity but more significant are the social dimensions- the Really Important Problems (RIP's) mentioned earlier are grounded in the quest of equity and social justice, ethical dimensions perhaps voiced infrequently but fundamental to the disciple. Perhaps the third edition of the handbook will contain an entry for the topic. (Calfee, 2006, pp.39-40).

[1] The first two authors are referring to the context within the U.S.A

Mathematics as a marginalizing force

The field of mathematics has been criticized for its academic elitism. There is a growing canon of studies which indicates that the institution of mathematics tends to marginalize women and minorities (Burton, 2004; Herzig, 2002). Moreover several studies have shown that the knowledge produced by the institution of mathematics is based on a patriarchal structure and a male-centered epistemology. There is also adequate empirical evidence in the U.S that academic fields related to mathematics continue to be predominantly male (Chipman, 1996; Seymour, 1995). Further, in the U.S, the representation of minorities (African America, Native American) at the post-graduate level is still miniscule (Seymour & Hewitt, 1997; Sriraman & Steinthorsdottir 2007, 2009). Mathematics has also historically served as the gatekeeper to numerous other areas of study. For instance in the hard sciences, schools of engineering and business typically rely on the Calculus sequence as a way to filter out students unable to fulfill program pre-requisites.

In numerous countries around the world, particularly in Asia, entry to government subsidized programs in engineering and the sciences is highly competitive and require students to score in the top 1 percentile in entrance exams in which mathematics is a major component. The situation is not so different in North America as evidenced in the importance of standardized tests like SAT or ACT to gain entry into college programs. It is not uncommon to hear politicians use schools' performance on mathematics assessments as a reference point to criticize public school programs and teachers (e.g., the passing of the No Child Left Behind Act in the U.S), and more recently the National Mathematics Advisory Panel (NMAP) report which criticizes almost all of the existing mathematics education research and advocates a back to basics push in the curricula and quantitative methodologies as the only acceptable mode of research inquiry. Issues of race, equity equal access and social justice find little or no place in the NMAP report (see Greer, 2008; Gutstein, 2008, 2009; Martin, 2008).

Mathematics seen in its entirety can be viewed as a means of empowerment as well as a means to oppress at the other end of the spectrum. For instance, Schoenfeld (2004) in his survey of the state of mathematics education in the U.S., wrote “Is mathematics for the elite or for the masses? Are there tensions between "excellence" and "equity"? Should mathematics be seen as a democratizing force or as a vehicle for maintaining the status quo?” (p.253). More recently, in his chapter representing mathematics education in the second edition of the *Handbook of Educational Psychology*, Schoenfeld (2006) points to research on equity and social justice as an increasingly important dimension of research for the field and cited the ongoing work of Gutstein as an exemplary example of such work.

Gutstein’s (2006) book, *Reading and Writing the World with Mathematics*, presents the possibilities for mathematics to serve as a means for critically understanding the reality within which we live. Inspired by Freire’s (1998) emancipatory work, Gutstein, a university educator and an activist, takes on the challenge of teaching a middle school class at Rivera, a pre-dominantly Latino neighborhood in Chicago. The motivation for doing so is to create/be a living example of an implemented blueprint for critical pedagogy in a mathematics classroom. Although politics is the last thing that teachers of mathematics may have in mind, Gutstein’s work reveals the intrinsically political nature of mathematics education. Nearly 30 years ago, Anyon (1980) described social class and the hidden curriculum of work in different elementary schools in the U.S as a function of their location in varying socio-economic neighborhoods. Anyon reported a “Flatlandesque[2]” world in which students from lower socio-economic classes

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[2] Flatland was a 19th century underground publication. The author of this book Edwin Abbott (1984) spins a satire about Victorian society in England by creating an isomorphic world called Flatland whose inhabitants are a

were essentially being educated to be compliant workers, good at following directions and the opportunity to use higher order thinking skills. Whereas the higher class students were educated in a way that emphasized critical thinking skills, communication and leadership skills to guarantee higher capital and managerial mob, Gutstein's more contemporary students were in a similar position to the situation described by Anyon nearly 30 years ago, namely in life and schooling circumstances which encouraged their current status quo. Gutstein (2006) sets the example for a pedagogy capable of creating a paradigmatic shift in students' mentality as to the nature and purpose of mathematical thinking; that is, the usefulness and the power of mathematics to understand the world and the inequities in the world around us. The book suggests that mathematics has been "accepted as apolitical, and this makes it difficult for researchers, teacher educators, teachers and pre-service teachers to conceptualize teaching and learning mathematics for social justice" (p. 207). Even the National Council of Teachers of Mathematics(2000) which are big on equity can be criticized as being utilitarian in nature with little or no discussion on teacher development in critical pedagogy. Gutstein, in his role as a classroom teacher, set up conditions that mediate a pedagogy for social justice where several carefully chosen mathematics projects are used to make sense of student's realities. These mathematics projects include real world data such as mortgage approval rates in bigger cities according to race; and the mis-information or distortion of land mass given in older maps using the Mercator projection. Interestingly Mercator maps came out during the peak of colonization[3].

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hierarchy of geometric shapes and exhibit the many peculiarities of 19th century England, including the oppression of lower classes and women.

[3] The mathematics behind the Mercator map has nothing to do with the way the map ended up being used for political purposes. A number of critical theorists who have no idea of the mathematics behind the map run around saying "the map was purposefully made that way" . Gerardus Mercator (1512-1594) created the map for navigational purposes with the goal of preserving conformality, i.e., angles of constant bearing crucial for plotting correct navigational courses on charts . In other words a line of constant bearing on a Mercator map is a rhumb line on the sphere. Conformality as achieved by Mercator with his projection came at the price of the distortion that occurred when projecting the sphere onto a flat piece of paper. The history of the map is also linked to the

Other projects include using the cost of a B-2 bomber to compute how many poorer students in that community could be put through university. The book gives a message of hope as well as the grimness of schooling for many minority students in the U.S. The value of Gutstein's approach lies in its goal to impact the social consciousness of students and a critical awareness of larger issues that impact their day to day life. The work of Gutstein sets a necessary example for a pedagogy of social justice emphasized in mathematics education literature in different parts of the world. For instance, Moreno and Trigo (2008) in their analysis of inequities in access to technology in Mexico wrote:

> We will also need to teach students to think critically about the ongoing changes in the world and about how these changes can affect educational and national realities. Access to knowledge cannot be regarded as a politically neutral issue because there is an obvious problem of exclusion for those who are on the margins of the educational process at any of its levels. Our inclusion in the contemporary world of globalization demands that we have the critical ability to transfuse scientific and technological developments into our educational realities. (p.319).

Skovsmose (2005) takes a more global stance and discusses critically the relations between mathematics, society, and citizenship. According to him, critical mathematics give challenges connected to issues of globalization, content and applications of mathematics, mathematics as a basis for actions in society, and on empowerment and mathematical literacy (mathemacy). In

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limitations of the Calculus available at that time period, and the difficulty of integrating the secant function (see Carslaw, 1924). Mercator himself comments, "…It is for these reasons that we have progressively increased the degrees of latitude towards each pole in proportion to the lengthening of the parallels with reference to the equator…" Mercator determined this vertical scaling through compass constructions. It was not until 1610 that Edward Wright, a Cambridge professor of mathematics and a navigational consultant to the East India Company, described a mathematical way to construct the Mercator map which produced a better approximation than the original.

earlier writings Skovsmose (1997, 2004) argued that if mathematics education can be organized in a way that challenges undemocratic features of society, then it could be called critical mathematics education. However he lamented that this education did not provide any recipe for teaching, which Gutstein's book does. So we challenge the reader to ponder on several questions raised by Skovsmose if they do read Gutstein's book. (1) Does mathematics have no social significance? (2) Can mathematics provide a crucial resource for social change? (3) How may mathematics and power be interrelated?

The third question above is answered from a feminist perspective in Burton's *Mathematicians as Enquirers* (date). The institution of academic mathematics has often been criticized as being both male dominated and setting a precedence for transmitting behaviors, teaching and learning practices that tend to alienate women. The sobering fact that women mathematicians are still by and large a minority in the mathematics profession today (Seymour, 1995; Seymour & Hewitt, 1997), in spite of numerous large scale initiatives by the National Science Foundation (in the U.S) to increase numbers of female students in graduate programs, necessitates we examine this problem from a different perspective. . Burton proposes an epistemological model of "coming to know mathematics" consisting of five interconnecting categories, namely the person and the social/cultural system, aesthetics, intuition/insight, multiple approaches, and connections. Grounded in the extensive literature base of mathematics, mathematics education, sociology of knowledge and feminist science, this model addresses four challenges to mathematics, namely "the challenges to objectivity, to homogeneity, to impersonality, and to incoherence." (p.17). In other words, Burton argues that it is time we challenged the four dominant views of mathematics which are:

- The Platonist objective view
- a homogenous discipline, which goes hand in hand with an objective stance;
- an impersonal, abstract presentation entity, complementing the view of an individualistic discipline, and the egotistical mathematician); and
- a non-connected “fragmented” discipline (as many learners experience it).

Burton conducted an empirical study with 70 mathematicians (35 male and 35 female), from 22 universities across the U.K and Ireland, to both generate and test the validity of her epistemological model which demolishes the four dominant views. In particular, Burton shows the different “trajectories” (personal, social, and cultural variables) that led the participants into a career in mathematics. These trajectories contradict the myth that mathematicians are “born” into the profession. The emerging contradiction between these mathematicians’ neo-Platonist belief about mathematics, despite the heterogeneity of the pathways into mathematics is discussed. The book gives an insight through various case studies of the contrast between female and male mathematician’s formative experiences when entering the field of professional mathematics. It seems to us that females seem to have to adapt to “males ways of knowing”. For instance the literature in gender studies has documented the preferred learning styles and classroom cultures that encourage female students are in stark contrast to the way mathematics is traditionally taught. In Burton’s book, one encounters the teaching of mathematics at universities in the didactically, teacher-centered “traditional” and authoritarian manner of lecturing, which conveys to students a “dead” perception of mathematics. The contradiction the book discusses is that this manner of teaching is in apposition to the excitement that mathematicians experience when doing research. Burton contends that educators need to gain an insight into the minds, beliefs, and practices of mathematicians because as is often the case at many universities, mathematicians often teach the content courses taken by prospective teachers. Further empirically showing that there exists a dichotomy between research practices and pedagogical practices among mathematicians sets up a sound research base for transmitting these findings to mathematicians. The ultimate hope of course is that mathematicians will begin to convey the creative and exciting side of their craft to the students in their classroom and to change the dominant epistemology of knowing in order to stop marginalizing female learners and learners of some racial and ethnic groups.

An interesting case study that illustrates Burton's thesis is the story of one mathematics department in the United States (Herzig, 2002). Herzig asked the rhetorical question of where all the students have gone, referring to high attrition rate of Ph.D. students in math programs. Similar to Burton's book, her study implies that many Ph.D. students experience discouragement and disillusionment in programs that offer limited opportunities for students to participate in authentic mathematical activities. Her findings also address what she calls "faculty beliefs about learning and teaching" where these beliefs contradict each other. Faculty use word such as "beauty, pleasure, delightful and pretty" (p. 185) when describing their work as mathematicians. On the contrary they use words such as "perseverance, persistence, stamina, tenacity, and pain" (p. 185) when talking about graduate students learning mathematics, thus, implying that a student either has what it takes or not. In this sense, these faculty were absolving themselves from all responsibility in students success' or lack there of.

The examples of research summarized have some implication for both the learning and teaching mathematics at all levels. It implies that we not only have to diversify faculties at university level but also diversify the mathematics we teach and the context in which we teach it. From a political and economical standpoint both are important to ensure more diverse groups of people gain entry and succeed in the profession of mathematicians. In an ever changing world and global economy multiple viewpoints other than male-dominated epistemologies are important to solve today problems.As mentioned before, efforts in increasing the participation of women in mathematics have not been very successful. One might ask why? The reasons might be the contrast between doing mathematics and learning mathematics. It is not enough to accept women and minority students into graduate studies on mathematics, there also has to be change in how students experience mathematics as students. Burton (2004) and Herzig (2002) offer ideas on how a mathematics department can analyze their department and restructure it in a way that more diverse groups of people might experience success in the field. If we look at the learning and teaching mathematics in grade school one can say the same thing. If the goal is to help students understand mathematics and encourage them to continue their studies in mathematics then studying of mathematics must include elements of what doing mathematics is. Gutstein gives one example when describing how to use mathematics to analyze the social structure in our society.

Democratization, Globalization and Ideologies

Numerous scholars like Ubiratan D'Ambrosio, Ole Skovsmose, Bill Atweh, Alan Schoenfeld, Rico Gutstein, Brian Greer, Swapna Mukhopadhyay among others have argued that mathematics education has everything to do with today's socio-cultural, political and economic scenario. In particular, mathematics education has much more to do with politics, in its broad sense, than with mathematics, in its inner sense (D'Ambrosio, 1990, 1994a, 1994b, 1998, 1999, 2007; Sriraman & Törner, 2008). Mathematics seen in its entirety can be viewed as a means of empowerment as well as a means to oppress at the other end of the spectrum. These issues are more generally addressed by Spring (2006), who summarizes the relationship between pedagogies and the economic needs of nation/states. His thesis is that the present need for nation/states to prepare workers for the global economy has resulted in the creation of an "educational security state" where an elaborate accountability-based system of testing is used to control teachers and students. Spring points out that:

> Both teachers and students become subservient to an industrial–consumer paradigm that integrates education and economic planning. This educational model has prevailed over classical forms of education such as Confucianism, Islam, and Christianity and their concerns with creating a just and ethical society through the analysis and discussion of sacred and classical texts. It has also prevailed over progressive pedagogy designed to prepare students to reconstruct society. In the 21st century, national school systems have similar grades and promotion plans, instructional methods, curriculum organization, and linkages between secondary and higher education. Most national school systems are organized to serve an industrial–consumer state…[I]n the industrial–consumer state, education is organized to serve the goal of economic growth. (p.105).

Therefore, in order to counter this organized push for eliminating progressive education, it is important that educators be open to alternative models of pedagogies which attempt to move beyond the current dominant "industrial consumer state" model of education.

Educational systems are heavily influenced by the social and cultural ideologies that characterize the particular society (Clark, 1997; Kim, 2005; Spring, 2006). Kim (2005) characterizes "western" systems of education as fostering creativity and entrepreneurship when compared to "eastern" systems where more emphasis is laid on compliance, memorization, and repetitive work. However East Asian countries stress the values of effort, hard work, perseverance and a general high regard for education and teachers from society with adequate funding for public schools and family support. Again in comparison, in the U.S., public schools are poorly funded, teachers are in general not adequately compensated nor supported by parents, and there is a decline in the number of students who graduate from high school (Haynes & Chalker, 1998; Hodgkinson, 1991) Among the western developed democratic nations, the U.S has the highest prison population proportion, 30% of whom are high school dropouts (Hodgkinson, 1991; Walmsley, 2007). In addition high school dropouts are 3.5 times more likely than successful graduates to be arrested (see Parent et al., 1994). For more recent statistics on prison population demographics visit http://www.ojp.gov/bjs/prisons.htm

In China, Japan and Korea, the writings of Confucius (551-479 BCE), which addressed a system *of morals and ethics, influenced the educational systems. The purpose of studying Confucian* texts was to create a citizenry that was moral and worked toward the general good of society. Competitive exams formed a cornerstone of this system, in order to select the best people for positions in the government. The modern day legacy of this system is the obsession of students in these societies to perform well on the highly competitive college entrance exams for the limited number of seats in the science and engineering tracks. The tension and contradiction within this system is apparent in the fact that although these societies value education, the examination system is highly constrictive, inhibits creativity and is used to stratify society in general. Late bloomers do not have a chance to succeed within such an educational system. In the U.S., despite the problems within the educational system and the general lack of enthusiasm from society to fund academic programs that benefit students, the system in general allows for second-chances, for individuals to pursue college later in life in spite of earlier setbacks.

On the other hand, for many students, particularly from poorer school districts, socio-economic circumstances may not allow for such second chances. The U.S model of an industrial-consumer state based on the capitalistic ideal of producing and consuming goods, forces students into circumstances which make it economically unfeasible particularly for students from poor socio-economic backgrounds to veer vocations and pursue higher education. Clearly both systems, based on different ideologies have strengths and weaknesses that are a function of their particular historical and cultural roots. Social change is possible within and across both systems but requires changes within cultural and socio-political ideals of eastern and western societies. Both systems have intrinsic flaws that undermine developing the talents of students. There are however solutions proposed by numerous educational philosophers and activists which reveal a synthesis of eastern and western ideas and provide for the possibility of systemic change for society (see Sriraman & Steinthorsdottir, 2009)

Looking Back at New Math (and its consequences) as an outcome of the Cold War

Sriraman & Törner (2008) wrote that it has become fashionable to criticize formal treatments of mathematics in the current post-constructivist phase of mathematics education research as well as to point to the shortcomings and failings of New Math. However the New math period was crucial from the point of view of sowing the seeds of reform in school curricula at all levels in numerous countries aligned with the United States in the cold war period as well as initiated systemic attempts at reforming teacher education. In fact many of the senior scholars in the field today, some of whom are part of this book and book series owe part of their formative experiences as future mathematicians and mathematics educators to the New Math period. In chapter 1 of the book we mentioned the prominent role that the Bourbakist, Jean Dieudonné played in initiating these changes and the aftermath of the 1959 Royaumont Seminar that made New Math into a more global "Western" phenomenon. Thus, the influence of prominent Bourbakists on New Math in Europe was instrumental in changing the face of mathematics education completely. We remind readers that the emergence of the discipline "Mathematics Education" in the beginning of the 20th century had a clear political motivation. This political motivation became amplified within the Modern Mathematics and New Math movements. Economic and strategic developments were the main supporters of the movements. Both the patronage of the OEEC (Organization for European Economic Co-operation) for the European movement and the public manipulation of the public opinion in the United States, are clear indications of the political motivation of the movements.

Mathematics, Technology and Society

Mathematics has long been a characteristic human activity. Artifacts found in Africa that are 37,000 years old have been interpreted as mathematical in nature. The first schools of mathematics are thought to have originated around 5000 BCE in the Near East where scribes – government taxation specialists – where trained in special methods of computation now known as arithmetic. Even in these earliest of schools, there is evidence of mathematics as a form of mental recreation, an art unto itself. This “abstract play” is particularly developed in Euclid’s *Elements* where little, if any, practical motivation is presented for the exhaustive body of work in geometry, ratio and number theory. Yet mathematics never escapes its practical roots. Trigonometry is developed to support exploration, mechanics and calculus are advanced to support military science, and statistics is invented to support the actuarial sciences. So, it is no surprise that mathematics has been characterized as the handmaiden of the sciences.

Given the historical interplay between the development of mathematical theory and its practical application in the sciences one is left to question how the nature of mathematics has changed in the more recent technological era. How has the rise of technology shaped the way that people learn and know mathematics? In particular, what has been the influence of the culture of technology on the popular understanding and teaching of mathematics?

In order to fully answer this question, we must first define what is meant by the “culture of technology”. The *device paradigm* is a helpful aid in characterizing this culture. Presented by Borgmann (1984) in *Technology and the Character of Contemporary Life*, the paradigm posits that a device consists of a commodity and a machinery. The qualities that characterize the commodity inherent to the device are its ubiquity, instantaneity, ease and safety. The qualities that characterize the machinery inherent to the device are an increasing sophistication, an ever-shrinking size and a concealment of inner workings. From a phenomenological point of view, as a device evolves, the commodity is increasingly turned towards the user, showcasing its utility, while the machinery becomes increasingly concealed and withdrawn from interaction with the user, hiding its inner workings.

A simple example can help the reader who is unfamiliar with this paradigm. Consider the human need for warmth. Here we can contrast the act of harvesting wood from the forest where it is felled, chopped, dried and stored to be later loaded and burned in a stove with the act of adjusting a modern thermostat in a home with a forced air furnace system. The example shows how the modern thermostat provides the commodity, heat, in a manner that is at once easy, ubiquitous, safe and instantaneous. In contrast, the older practice provides heat at some risk to safety - consider felling trees and sawing logs - the process is slow and laborious and the heat provided is anything but instantaneous. With regard to the machinery, the ductwork, furnace, gas lines, and filters of a modern forced air heating system are hidden in the floor and walls and can only be serviced by a licensed professional. In contrast, the woodstove is not concealed in the home for which it provides heat and its workings are easy to understand and self-evident.

Borgmann (1984) argues that the culture of technology can be characterized as a transformation of usage of traditional things with devices, as understood according to the device paradigm. So, traditional activities, such as those that surround the act of wood-heating a home, are replaced with devices, such as a modern forced air furnace system. The paradigm explains the need for an increasing commitment to mechanization and specialization in the workplace in order to insure the delivery of commodities of necessity such as food, shelter, water and warmth. The paradigm also exemplifies the increasing commodities-driven marketplace which has given rise to the consumerism that seems to accompany technological advancement. Here, the characterization is one in which the meaninglessness of labor is alleviated by the consumption of commodity.

Applied to education, we see an increasing focus on the improvement and maintenance of the machinery of technology. Education becomes the means by which we prepare individuals to “compete” in the modern marketplace in order to be beneficiaries of world commodities. There is a growing focus on specialization in order to tend to the ever-growing sophistication present in the machinery. Society's growing commitment to technology has the effect of elevating the importance of science, mathematics, and other technologically related fields.

As the need for a technologically skilled work force grows there is a demand for "technical" education which becomes a commodity itself. Students become consumers of the services provided by education. Education becomes ubiquitous and instantaneous – available anywhere of on-line. Education becomes safe and easy – grades are inflated, underachievement is rewarded. The machinery of education becomes increasingly sophisticated and concealed - governed by technical documents and a host of administrators.

And so it becomes apparent that the effects of technology, as understood according to the device paradigm, on the popular understanding of mathematics are many. There is an increasing agreement that mathematics is an "important subject" in public education, one which should be given special significance. This implication flows from the understanding that a technological society, one that has embraced the commodity-machinery duality that technology presents, must increasingly maintain its machinery in order to insure an uninterrupted flow of commodities which the machinery of technology provides. It is mathematics that makes machinery possible. Thus mathematics is given special status. This phenomenon is historically documented in the replacement of religion with mathematics in early American universities, the post-Sputnik educational race in mathematics and science, as well as current standardized testing practices which designate up to half of a student's scholastic aptitude according to proficiency in mathematics.

If we place the subject of mathematics within the paradigm itself we can easily see evidence of the machinery-commodity duality. The commodity is recognizable as "computational power" which serves those who construct the technological world: architects, engineers, and scientists. This commodity provides the ability to predict navigation, risk, trajectory, growth and structure. The machinery is that which provides for computational power, it is mathematical theory. So, according to Borgmann's thesis, a society that embraces such a paradigm should expect the commodity of computational power to become more instantaneous, ubiquitous, safe and easy. Borgmann's thesis also predicts mathematical theory, the machinery of computational power, to be "turned away" from the user, to shrink in size, and to grow ever more concealed.

Indeed we find this to be the case in the modern age. Computation can be characterized as instantaneous, ubiquitous, safe and easy. One need only consider the accurate calculation of a logarithm. In today's technological society, such a calculation is carried out by calculator or computer whereas previous pre-technological societies carried out such a calculation painstakingly by hand. The modern calculation is quick and easy, one need only push a few buttons. Due to the ubiquity of computers and calculators, the modern calculation can be carried out nearly everywhere. Finally, the calculation represents no risk whatsoever, not even one of "wasting time". In contrast, the pre-technological calculation of a logarithm is a characteristically slow and difficult task requiring a skill which is acquired through considerable education. The calculation is also carried out with some risk of *miscalculation*. In the example we see a demonstration that the machinery of computation, mathematical theory, is increasingly shrinking in size, becoming more concealed and growing in sophistication. Indeed, the modern calculation of a logarithm leaves one with a sense of mystery: there is no indication of how the computation was carried out. Thus, the modern calculator of a logarithm finds the mathematical theory to be irrelevant, concealed and, in terms of an expanding mathematical ignorance, growing in its sophistication.

In light of the device paradigm, the effects of technology on the popular notions of mathematics become quite apparent. There is the popular alignment of mathematics with computation. There is an ever-growing popular notion that the inner workings of mathematics are overly-sophisticated, concealed and less important. So, popular mathematics becomes more dependent on algorithms (calculators) and what Skemp (1987) has characterized as "rules without reasons".

The popular understanding of mathematics becomes the basis for teaching mathematics in the technological age. The teaching of subject in the technological era transforms into what Ernest (1988) and others (Benacerraf & Putnam, 1964; Davis & Hersh, 1980; Lakatos, 1976) have termed the "instrumentalist" approach to mathematics education. The instrumentalist view is the belief that mathematics consists of the, "accumulation of facts, rules and skills that are to be used by the trained artisan…in the pursuance of some external end… [it] is a set of unrelated but utilitarian rules and facts" (Ernest, 1988). In light of the device paradigm it seems appropriate that the instrumentalist view can be characterized as the by-product of the technological era and its coercive effects on education, a hypertrophic version of the applied tradition in the science. Here the instruction is simply a means of achieving computational proficiency. In effect, mathematics becomes a device whose machinery is hidden from view and whose computational results are showcased as commodity. Notably absent are the historically mathematical notions of abstraction, creativity, conjecture and proof. Also excluded are any traces of aesthetics, beauty or art, which are deemed "non-mathematical" by the instrumentalist approach. Simply put, education in mathematics grows ever more synonymous with blind algorithmic computation.

In summary, the effects of technology on the popular understanding of mathematics and mathematics education are illuminated by the device paradigm. The paradigm argues that technology increasingly replaces traditional things and practices with devices. We have shown that mathematics, understood as a technological device, consists of a machinery, *mathematical theory*, and a commodity, *computational results*. Computation is increasingly presented as instantaneous, ubiquitous, safe and easy, while, mathematical theory shrinks in size, grows more concealed and becomes more sophisticated to the popular user of mathematics. Mathematical education then reflects these notions, becoming highly instrumental in approach, stressing facts, rules and skills, and producing educational outcomes that are disassociated from theory which denies the learner from any deep understanding of mathematical concepts.

What does the future hold? A critical view of the field

Three decades of research in mathematics has concerned itself with issues of equity among social groups. The results of this line of research are clear: females, minorities, speakers of English as a second language and those of lower social economic status experience significant inequities in educational outcomes tied to mathematics. Perhaps most notable among these outcomes is the fact that these social groups are all underrepresented in mathematics-related occupations (Carey et al., 1995). While inequity in mathematics is easily identified, the underlying causes are more complex in nature. This leads to the question at hand: does the institution of mathematics propagate beliefs, norms and practices that marginalize certain social groups?

The common reaction to the question posed is, “How can the institution of mathematics interact with social groups if it is simply the product of logic?” It is argued that mathematics, envisioned as a body of pure and absolute knowledge, has no socially determined features.

Therefore, it cannot "interact" with social groups in any meaningful way. This Platonic conception of mathematics portrays the institution as value-free, existing in a realm that is "above" other sciences where socially-determined features are more easily recognizable.

Hersh (1991) argues that the myths of unity, objectivity, universality and certainty are propagated by the institute of mathematics through a frontside-backside regionalism in its social structure. The frontside portrays mathematics in "finished form" to the public as formal, precise, ordered and abstract. The backside is characterized as the "backstage" mathematics of mathematicians: informal, messy, disordered and intuitive. Hersh's essay points to the fact that "all is not as it would seem" in mathematics, that there is a "behind closed doors" social element which goes unrecognized.

It is this doubt that "all is not as it would seem" in mathematics that has prompted the rise of social constructivism as a philosophy of mathematics. Here, the creation of mathematical knowledge is presented as the result of a heuristic cycle in which subjective knowledge of mathematicians is presented to the public where it is undergoes a process of scrutiny and criticism. This period of evaluation leads to either rejection or (social) acceptance of the conjecture as "tentative" mathematical knowledge thereby becoming "objective" knowledge. Finally, the successful acceptance of new mathematical knowledge always remains open to refutation or revision (Ernest, 1991).

If we accept that mathematical knowledge is constructed in such a fashion then we can recognize that there is an inherent social aspect to the formulation of mathematical knowledge. The connection between mathematics and certain social groups can then be critiqued by examining the social construction of mathematical knowledge and the social systems in which mathematics is created, taught and used (Martin, 1997). Here we critically assess the questions:

What counts as mathematical knowledge? What do we study in mathematics? Who will teach mathematics? And, what counts as learning in mathematics? A critical analysis of these questions will give us a fuller understanding of the interactions between mathematics and the social groups in question.

What counts as mathematics? Mathematics as a socially constructed knowledge is subject to social influence. Historically we can see the "social imprint" of mathematical knowledge in the development of arithmetic to support taxation, trigonometry to support navigation, mechanics and calculus to support military science, and statistics to support actuarial sciences. Martin (1987) points out that the field of operations research was prompted by military needs in World War II and continues to be "maintained by continuing military interest" (p. 159). In the modern era, Hodgkin (cited in Martin, 1997) argues that the rise of "mathematics of computation" in mathematical study is the result of the influences of industrialization, meeting its needs for the development of computationally intensive technologies. So, what counts as mathematics is at least partly determined by the needs of society, these needs are linked to the social interests of those who hold power in society.

What do we study in mathematics? In modern schools the answer can be easily found: arithmetic, geometry, algebra, trigonometry, calculus, and so on. It is a science, we are told, which initiated with the ancient Greeks and was subsequently rediscovered in the Renaissance and developed by Europeans and their cultural descendants. It is what Joseph (1997) calls "the classical Eurocentric trajectory" (p. 63). Many historical revisionists have pointed out that myths about the history of mathematics are pervasive in the common textbook and classroom portrayal of the subject. Euclid, who both lived and studied in Alexandria in modern day Egypt, is portrayed as "a fair Greek not even sunburned by the Egyptian sun" (Powell & Frankenstein, 1997a, p. 52). Notably absent are Arab, Indian, and Chinese contributions to the science. Powell and Frankenstein (1997a) note that among the seventy-two scientists (all male) whose names are inscribed on the Eiffel Tower for their contributions to the mathematical theory of elasticity of metals which makes the tower possible, notably absent is name of Sophie Germain a significant female contributor to the science. What do we study in mathematics? We study the inventions of mostly white, European men – the dominant culture in the world today. Some have pointed out that this portrayal aligns scientific progress with European culture – leaving non-Europeans with the difficult choice of cultural assimilation in order to enjoy the benefits that scientific progress has provided (Powell & Frankenstein, 1997a).

Who will teach mathematics? Well, naturally, teachers trained in mathematics will teach mathematics. But here, again, the social effects of the construction of mathematical knowledge can be seen to have a particularly influential effect on the learning of mathematics in certain social groups. A study by Hill, Rowan and Ball (2005) found that the specialized content knowledge of mathematics possessed by teachers significantly affected student gains in mathematical knowledge over the course a school year. In the discussion of their findings they note that the measurement of teacher's mathematical knowledge was negatively correlated with the socio-economic status of the students. That is, poorly trained teachers, in terms of content knowledge of mathematics, have a tendency to teach in poorer schools. They go on to note that at least a portion of the gap in student achievement routinely noted in the National Assessment of Educational Progress and other assessments "might result from teachers with less mathematical knowledge teaching more [economically] disadvantaged students" (p. 400). And so it becomes apparent that "who will teach mathematics" interacts with certain social groups according to economic status. Here, we can characterize the social construction of mathematical knowledge facilitated or disadvantaged according to our membership in the dominant economic class.

What counts for learning in mathematics? If we avoid the temptation of objective absolutism in mathematics it becomes evident that even assessment can be seen in a "social" context that is differentially applied to certain social groups. Walkerdine (1997) argues that "mathematical truth" understood socially is inherently linked "with the truths of management and government which aim to regulate the subject" (p. 204). Thus the imagined "objective" assessment in mathematics can be seen as the extension of an organizational and managerial scheme which ultimately "sorts" pupils according to ability. Furthermore, Walkerdine notes that ability is measured in terms of "dominant" socially constructed notions in mathematics, thus, assessment in mathematics can be seen as a subtle means of "sorting" academic advancement according to predetermined socio-cultural factors. Powell & Frankenstien (1997b) and D'Ambrosio (1997) have also noted this phenomenon in their case study review of individuals possessing rich and varied "ethno-mathematical" knowledge which does not serve for advancement in school settings. And so we see that "what counts for learning in mathematics" interacts favorably with dominant social groups and unfavorably with social groups which occupy the margins of society.

Questions concerning the interaction of the institution of mathematics and certain social groups must start with an admission that mathematics is a socially constructed human invention. A Platonic denial of any interaction fails to recognize that mathematical concepts do not exist in isolation, but, are organized by humans with an intended purpose. In the social organization of the subject, we can see that mathematics *does* interact with social groups such as females, minorities, non-native speakers of English and those of lower social economic status. As nonmembers of the dominant class these social groups are systematically disadvantaged. Mathematics does not serve their interests but rather reflects the interests of the dominant culture. Mathematics overlooks their historical contributions to the science and implies a necessary assimilation in the dominant culture in order to enjoy the "rewards" that the science has to offer. The institution of mathematics disadvantages marginalized social groups by providing them with poorer teachers. Finally such groups are assessed in mathematics in ways that maintain social structures while simultaneously devaluing rich and varied ethno-mathematical knowledge.

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