MATHEMATICS FOR A BROKEN, BEAUTIFUL WORLD: A MODULAR RESOURCE PACKAGE FOR LATE SECONDARY AND EARLY POST-SECONDARY MATH EDUCATORS

An Independent Learning Project Presented by

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ABSTRACT

This Independent Learning Project (ILP) is an attempt to clarify how and why mathematics really matters in the lives of students. It begins with a framing of the typical disconnection between students' lives and modern-day school mathematics and continues with a review of scholarly research exploring some of the causes, components, and remedies of that disconnection. Following this review is an original curricular resource package for mathematics educators who are working at late secondary and early post-secondary levels. This resource package includes materials that have been organized into flexible teaching modules and that are designed to facilitate educators' (re-)connection of math with contemporary issues of global concern. Finally, the ILP concludes with some reflections about the process of developing the resource package as well as expectations about its anticipated impacts and implementation opportunities.

To the sharpest point, this ILP recognizes and aims to contribute to the burgeoning movement of *humane mathematics education*—mathematics teaching and learning that strives to help students to *make good sense of and make positive change in their world*.

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Chapter I

Rationale

"When are we ever going to need to *use* this?" Countless students of mathematics have uttered this question, and countless teachers of mathematics have struggled to answer it. And though it may have arisen occasionally as an attempt to avoid difficult academic material, this question has just as often been genuine and directly aimed at the heart of an important issue in contemporary mathematics education. For it is a question pointing to a fundamental mismatch and lack of resonance between much of modern-day mathematics curricula and the actual realities of students' lived experiences in their homes and communities. In other words, many students who ask that question today are really claiming—and rightly so—that the mathematics they are being asked to learn is largely irrelevant to their lives.

To my mind, the essential problem underlying the classic question of the usefulness of school mathematics is that when students experience mathematics as irrelevant, mathematics education has fallen short of its goals. Neither the student nor the subject is done justice in that case. It is my strong conviction that students today possess amazing potential to become agents of positive and creative change in a world beset by ecological, economic and cultural crises, but that today's students will fully realize that potential only if and when the academic subjects they encounter—including and perhaps especially mathematics—connect deeply with their own pressing concerns and passions. What Schumacher (1973) said about education in general can be extended, it seems to me, to the special case of mathematics:

> When people ask for education they normally mean something more than mere training, something more than mere knowledge of facts, and something more than a mere diversion. Maybe they cannot themselves formulate precisely what they are looking for;

> but I think what they are really looking for is ideas that would make the world, and their own lives, intelligible to them. (p. 68)

Mathematics, as far as I understand and appreciate it, is full of such ideas—ideas that have the power to nurture intelligibility. Thus, math seen as a body of knowledge and insight—as a unique language for understanding and experiencing the world—can and should be an effective tool in the hands of students. As one educator so aptly put it, "Students need to be prepared through their mathematics education to investigate and critique injustice, and to challenge, in words and actions, oppressive structures and acts—that is, to 'read and write the world' with mathematics" (Gutstein, 2006, p. 4). When mathematics fulfills this role of helping students to better understand the needs of their world and to develop appropriate and creative ways to meet those needs, I call it *humane mathematics*. In shortest summary, humane mathematics is mathematics teaching and learning that is explicitly designed to guide students to *make good sense of and make positive change in their world.* In concrete practice, humane mathematics might involve an extensive exploration of the basic principles of the mathematics of finance—introduced by way of actual accounts of defaulted mortgages, say—in order to shed some light on events like the recent global economic "meltdown" or "downturn" and therefore to enable students to recognize and respond to the warning signs of such crises in the future. Similarly, a developed fluency in the primary principles of statistics could help students critically appraise the news they receive from various media and can help them uncover biases or prejudices that may be operative in the acquisition and promulgation of statistical evidence in those media.

Mathematics as an academic subject can serve students ways such as these, however, only if and when its rigor, beauty, and pertinence are communicated clearly. In short, students and the mathematics they learn ought to be respected more fully than has typically been the case.

I believe that it was as a student myself that I first began to recognize the gap between standard curricular structures in mathematics and the realization of the potential of math studies to awaken, inspire, equip and empower. It was not for want of good teaching, either. On the contrary—I received excellent instruction in mathematics in both high school and college, from teachers who cared deeply about their subject and their students. But something in the *structure* of mathematics education and in the vision of its purpose seemed to be missing. I felt that somehow the curriculum was neither showing me nor encouraging me to explore the most insightful and pertinent applications of the concepts I was studying. That feeling stayed with me—in fact, grew more acute—once I began to teach mathematics courses at secondary and early post-secondary levels. And I still have that same nagging feeling today. It is largely for this reason that I propose to undertake research in this Independent Learning Project (ILP) into the most effective ways of incorporating relevant and critical mathematics into the prevalent current systems of mathematics education.

So what do I hope to learn from my ILP research? I want to discover more about the visionary ideas and concrete methods that are trailblazing humane mathematics education. I want to learn about what is possible in this emerging area and the ways in which humane mathematics can inspire inquiry and compassion among students of mathematics. I want to reinvigorate my passion for the beauty, rigor and relevance of the powerful language of mathematics. And in the process of developing my ILP, I hope, of course, to become a more sensitive and effective mathematics educator myself.

Goals

With this background inspiration and motivation in mind, I can now identify the primary goals of my ILP:

1. To begin with, and in the broadest sense, I will strive in my ILP to research and further develop the new and emerging practice of humane mathematics education.
2. My project will target mathematics educators and learners who are from late secondary (grades 11 and 12) and early post-secondary (first-year college or university) levels and who are teaching and learning primarily within a North American context. The project will aim to provide those teachers and students with an enhanced understanding of some of the key numerical or quantitative characteristics of the contemporary world. These mathematical elements will be communicated with a view to helping teachers and students deepen their practice of compassion vis-à-vis other people, nonhuman animals, and the environment.
3. Most concretely, I aim to produce for mathematics educators of late secondary and early post-secondary levels a *modular resource package* entitled "Mathematics for a Broken, Beautiful World." The package will include three major modules—topic areas commonly found in mathematics curricula worldwide: basic probability theory, financial mathematics, and the study of functions and rates of change (up to and including differential calculus). Each module will be introduced by way of a current and authentic news story or actual account that inspires attention and helps to render the mathematics "real" for both educators and learners. It will then include an in-depth lesson plan exploring a major conceptual principle from that module's mathematical topic area. The lesson will be flexible in length and easily adaptable to various teaching contexts. Finally, each module will conclude with a list of resources as well as ideas for possible extensions, action options and "real world projects" that are pertinent to the topic area and that teachers and students could undertake in their specific locales.

4. The structure and components of each module lesson will be designed to help mathematics educators encourage their students to pursue their own mathematics "problems"—that is, questions involving quantitative reasoning that are relevant to their own lives and to the other people, nonhuman animals and natural environments that surround them. The module lessons will encourage and empower educators to help students take active and leading roles in mathematical investigations. One of the ways this will happen is through the provision of pertinent links to community, textual and web-based resources that are available to learners.

Problem Statement

"Mathematics for a Broken, Beautiful World," the modular resource package I intend to research and develop for this ILP, addresses a general information gap. Students, teachers, and education community members need to learn more about the possibilities of humane mathematics education. The reality is that the current global situation is one marked by social inequalities, environmental collapse, and various forms of political and cultural instability. It is important to "have our heads around the numbers" in such a critical situation. What I will be concerned with in my research, therefore, is the capacity of mathematics teachers and students to be influences for positive change in their communities—particularly in the areas of their lives that may be susceptible to forms of injustice, inequity, or abuse. "In today's world, economic access and full citizenship depend crucially on math and science literacy" (Moses & Cobb, 2002, p. 5). If this is indeed the case, then the problem addressed by my ILP is best seen, succinctly, as *how to best connect mathematics education to students' real lives and concerns*. My hope is that my project will do exactly this—will help mathematics educators better understand and communicate quantitative analysis as a key form of critical thinking and as an essential civic and

political activity—as important as literacy for an engaged global citizenry, and equally universal in importance.

I believe it is important to note at this point that my research and investigation for this ILP is concerned with both the *process* and *content* of what I am calling humane mathematics education. The centrality of both of these elements was emphasized by Stocker (2008) in his excellent resource book *Maththatmatters*, a text that is a major inspiration and model for my own ILP. I concur with Stocker in his assessment that the two intertwined problems of *how* we teach and *what* we teach are the most pressing issues in mathematics education today. I hope for my ILP to be part of broader efforts to revitalize and update both the process and content of contemporary mathematics education.

The predominant model in math instruction today seems to be one that follows the "banking" concept of education as described by the late Brazilian educator Freire (1970, 1993). On the process side, this means that the prevalent method is for mathematics teachers to "deposit" information into the minds of more or less passive students in ongoing preparation for assessments of concept retention. This method is heavy on rote memorization techniques (for example, of formulae) and "regurgitation" on quizzes and tests. And on the content side, the predominant model implies that the primary ideas in the curriculum are deemed not so much as worthy subjects of study themselves (with any sort of practical relevance or application), but rather only as stepping stones on the way to *more* math. Thus one of the more common responses to the question, "When are we ever going to use this?" is the obviously limited reply, "In next year's math course."

The essential problem here, once again, is that neither the student nor the mathematics is done justice. Mathematics can be a powerful tool in the hands of students, and it will be, if those students are given to see the deepest relevance and insight of the subject, if they are empowered

to ask their own critical questions using the language of quantitative reasoning, and if they are encouraged to pursue their own answers and solutions to the questions they generate.

Population

The research and formation of my ILP will most directly benefit mathematics educators and students at the late secondary (grades 11 and 12) and early post-secondary (first-year college or university) levels. This is indeed a large potential audience, since mathematics is an academic subject of nearly universal requirement at those levels.

The modular resource package will be designed in such a way that maximizes appeal and convenience for educators. In particular, it will especially benefit those educators who are presently unable to make extensive choices regarding curricular requirements and/or who cannot implement larger-scale structural changes in the current systems of math instruction. Many math teachers experience a good deal of pressure to "fit in" all of the required curriculum elements in the time span of a given course. So I will strive, in the development of "Mathematics for a Broken, Beautiful World," to make it easy for such educators to use the modules as convenient entrance points for incorporating humane mathematics elements into their course planning. This is largely why the modular themes correspond to widely common topic areas in late secondary and early post-secondary mathematics curricula. It is why the lesson and project suggestions within each module will be easily extractable and adaptable to a variety of educational contexts. And it is also why, as outlined below, I will undertake to research current exemplary practices among educators in the emerging area of humane mathematics.

Methodology

In order to proceed with my ILP, I will undertake both scholarly and non-scholarly research. Within the context of scholarly research I plan to pursue three categories of inquiry:

1. What are some current exemplary practices for incorporating cultural, ecological, and economic justice issues in mathematics education?
2. What constitutes adequate and effective numeracy for responsible global citizenship?
3. What can mathematics education add to critical current conversations about issues that concern people, nonhuman animals and the environment, and can humane math education enhance the practice of compassion for the students and teachers involved in those conversations?

I will investigate these questions by reading a number of current articles from scholarly sources and discussing those articles in the literature review that constitutes Chapter 2 of the ILP.

To supplement my scholarly research, I will also pursue a number of non-scholarly research avenues. For instance, I will gather and select pertinent information from various textual and internet-based collections of lesson plan ideas that may relate to the vision and spirit of the modular resource package. Secondly, I will consult a few mathematics educators in my local community who are working on issues of equity in math education, and who will be able to provide me with some guidance in my research. Third, I will have the opportunity to pilot at least some elements of the developing modules in the context of two mathematics courses that I will be teaching to new undergraduates at the Fredericton campus of the University of New Brunswick in Canada during the upcoming academic year.

In general, I do not anticipate any major obstacles to my research. Indeed, I expect to discover a healthy number of pertinent resources. The largest challenge I can foresee is in focusing my research—choosing wisely from among the available resources and streamlining the presentation of both the literature review and the modular resource package.

Chapter II

Introduction

At least three areas of current and ongoing academic investigation shed valuable light on issues pertinent to my ILP. First, a number of educators have experimented with and reflected on effective ways to infuse mathematics education with social justice sensitivities. Second, math education practitioners have clarified the precise meaning and implications of numeracy (or quantitative literacy) for competent global citizenship. And third, educators have explored the possibilities for mathematics to make meaningful contributions to broader conversations about justice and compassion in education.

Exemplary Practices in Humane Math Education

Fortunately, various pioneering efforts in humane mathematics education—particularly in the area of social justice—have already been made. For instance, Root (2009) described a first-year college seminar course that took a quantitative approach to issues of social justice. Gutstein (2007) reported on a two-year study of teaching and learning for social justice in a middle-school mathematics classroom in a Latino/a community in Chicago. Lesser (2007) and Winter (2007) suggested ways to inform the teaching of undergraduate-level courses in statistics and technical subjects, respectively, with social justice concerns. And Boaler (2006) described a successful reform approach to mathematics instruction in an urban high school setting.

Root's (2009) college level seminar course included three primary structural elements: modular academic content, a service-learning experience, and a series of writing assignments. Though not a course in mathematics or quantitative literacy per se, the course took "a quantitatively-rich approach to issues of social justice" and provided students "opportunities to reflect on the quantitative literacy that they have, how they got it, and how to apply it to issues of social justice" (p. 39). The explicit aim of the course was to "convey an appreciation for the

value of quantitative literacy for reasons beyond economic competitiveness" (p. 39), and it strove to achieve that aim by linking the mathematical backgrounds and capabilities of the students to social justice issues of concern to them. Root's course was successful in meeting its primary goal as students reported "an increased appreciation for their own quantitative literacy and for the value of quantitative literacy in society at large" (p. 42).

Gutstein's (2007) approach was similar to Root's in its emphasis on social justice issues of pressing interest to the students involved. Over the span of two years (seventh and eighth grades) Gutstein's students undertook a series of 17 "real-world projects" in which they "investigated racism and other injustices using mathematics as a key analytical tool" (p. 426). The overarching goal was to develop student agency and the theoretical framework was inspired largely by the work of Paulo Freire (specifically, his problem-posing strategies) and the historical efforts of African Americans for emancipatory education. What Gutstein found was that his pedagogy enhanced the development of student agency by connecting mathematics as an important and effective analytical tool with the reality of larger social movements for justice. On the one hand, "problematizing students' social realities within mathematics class provided opportunities to learn mathematics—read the word—and deepen sociopolitical understanding—read the world—at the same time" (p. 430). And on the other, for Gutstein's students "the opportunity to talk with parents and neighbors and share mathematical analyses, and to actually participate in the struggle, at whatever level, was integral to the process" (p. 433).

Lesser (2007), operating out of the subject-specific context of statistics education, offered a number of practical suggestions for college-level educators with social justice issues in mind. Indeed, his article was somewhat of an overview of the most current and effective practices in teaching statistics using social justice (TSSJ). Lesser defined TSSJ as "the teaching of statistics with nontrivial inclusion of examples related to social justice, offering opportunities for students

to reflect upon the context of these examples as they learn or apply the associated statistical content" (p. 3). Such examples, many of which Lesser described briefly and/or referenced throughout his article, encourage students "to ask critical questions about operational definitions of variables" (p. 5)—that is, about mathematical terminology and its implications. Lesser also pointed out that social justice examples built on authentic statistical data sets "support student engagement" (p. 10) with the topics and issues involved.

Winter (2007) described an undergraduate instructional model for the teaching of science, technology, engineering, and mathematics (STEM) disciplines. Winter's model intertwined "the technical learning characteristic of STEM disciplines with experiences and information to allow students to make better sense of some of the challenges and problems faced by other peoples and other cultures" (p. 98). Practically speaking, his model began with "introducing sociocultural phenomena" with readings, video clips, and activities or games to prepare for the mathematical work. After this preliminary exposure to an issue, students were presented with a problem or extended question and provided with a structured worksheet to guide them through the application of mathematical tools to the problem (p. 98). Upon reformulating the given social problem in mathematical terms with the aid of the worksheet and then solving the mathematical "version," students completed a "cycle of learning" by interpreting the meaning of their solution in light of the original context as well as with regards to any broader implications of their results (pp. 98-99). Winter found that the use of his model not only "increased students' general knowledge without sacrificing mathematical performance" (p. 104), but also impacted students positively in other ways less easily measured than those two standards.

Finally, Boaler (2006) described the Railside approach that was the subject of some of her own research into effective and equitable mathematics pedagogy. Railside High School (a pseudonym), an urban school in California, employed "a reform-oriented approach to

mathematics" (p. 365). Boaler and her research colleagues found that "at Railside, students learned more, enjoyed mathematics more, and progressed to higher levels of mathematics" than did students at two other schools employing "traditional methods of demonstration and practice" (p. 365). What made the difference? According to Boaler, five key features of the Railside curriculum were critical the students' success in mathematics at the school: departmental collaboration among teachers, shared responsibility among students, heterogeneous classes, block scheduling of class periods, and "group-worthy" problems involving multidimensional perspectives and methods.

A number of important themes emerged relating to the aforementioned efforts in humane mathematics education. First, every article contained a strong emphasis on the central process of *connecting* mathematics to students' real lives by way of relevant problem-based learning activities. The quality of student experience and success in math classes seems to be directly proportional to the level of appropriate and authentic contextualization of the problems investigated in those classes. As Root (2009) expressed it, "more students will be able to master more mathematical abstraction if they see connections between the fundamentals of mathematics and their lives and concerns outside the mathematics classroom" (p. 42). This means that pertinent, actual data sets and relevant related examples should be sought by educators (Lesser, 2007) and formed into coherent "real-life" problems and projects for—and sometimes by—students (Boaler, 2006; Gutstein, 2007; Winter, 2007). It also means that mathematics educators need to remain open to and prepared for the possibility of controversy in their classrooms (Lesser, 2007; Winter, 2007), since many of the most pressing contemporary issues facing students are multifaceted and complex. The salient point is that students deserve to be directly and personally involved in the objects of their studies, even their mathematical studies.

Secondly, the articles gave voice to concerns regarding the challenges of combining social justice concerns with mathematical concepts. Winter (2007) acknowledged the contention that large amounts of class time spent in discussion about social and cultural issues might undermine the technical content of STEM courses. Moreover, Lesser (2007) recognized various "implementation considerations" (p. 10) like time constraints and lack of precedent in the teaching environment, and he emphasized that the inclusion of social justice examples in statistics education ought to be "nontrivial" (p. 3). Indeed, the worry over the trivialization of mathematics concepts and social justice concerns in the process of their pedagogical combination is a central feature of the discourse on humane mathematics education and is echoed in a number of other sources (Gutstein, 2006; Nolan, 2009; Stocker, 2008). That is to say, it appears to be a widespread concern that mathematical concepts and sociocultural concerns are often "dumbed down" when they are put together. But the five primary sources consulted in this inquiry into exemplary practices certainly seem to be in agreement that the combination of mathematics with social justice—when achieved as a careful *infusion* rather than a perfunctory *grafting*—does in fact enhance students' understanding of *both* the mathematical concepts and the social justice issues at stake.

Third and finally, all of the sources consulted in this category made the claim—implicitly or explicitly—that effective humane math education enterprises are built on a dual foundation: a deep and practical *respect* for students, and an expansive *vision* of their capacities for making positive change in their own lives and in the world at large. Lesser (2007) focused his discussion on the underlying goal of student empowerment and enhanced engagement. Root (2009) emphasized the importance of providing new and challenging types of learning opportunities to students, and Winter (2007) mentioned the important positive impacts his instructional model activities had on individual students. Boaler (2006) noted that the Railside approach

"transformed students' lives by helping them to see mathematics as a part of their future and by providing them with the quantitative reasoning capabilities needed to function in an increasingly technological and global economy" (p. 365). But perhaps the strongest statement on behalf of students (and educators, for that matter) came from Gutstein (2007): "We can take . . . an orientation toward students that sees them as conscious subjects in the struggles for humanity and liberation, and that creates conditions for students to become agents of change toward social justice" (pp. 437-438). This hopeful closing note leads directly into the next category of inquiry.

Numeracy for Citizenship

A second category of research pertinent to my ILP is the exploration of what constitutes adequate and effective numeracy for responsible global citizenship. Embedded in this exploration are really two distinct questions: (1) *What* is numeracy? and (2) *Why* do learners need to have it? As for the first question, regarding the definition and/or description of numeracy—or equivalently here, quantitative literacy (QL)—a number of scholars have weighed in with important insights. Perhaps the briefest and pithiest definition of quantitative literacy was provided by Burkhardt (2008): "QL is *thinking with mathematics about problems in everyday life*" (p. 138). Wiest, Higgins and Frost (2007) helped to flesh out this concise definition. They described quantitative literacy as "an inclination and ability to make reasoned decisions using general world knowledge and fundamental mathematics in authentic, everyday circumstances" (p. 48). Wiest et al. went on to claim that "quantitative literacy involves knowing how to apply essential mathematics skills broadly across varied real-world situations" (p. 48).

So of what exactly does "fundamental" or "essential" mathematics consist? What are the key math skills to be learned by students? According to Wiest and her colleagues, although "no collective knowledge/skill set has been mutually established" (p. 48) by those engaged in conversations about QL, a set of frequently noted foundational skills can be identified:

> At the forefront are facility with numbers (e.g., computational skill and number sense), statistical and probabilistic knowledge and reasoning (including data representation and interpretation in graphic and other forms), reasoning and problem-solving skills, and general and technical communication skills. Other concepts and skills might include a basic command of geometry, measurement, proportional reasoning, algebra, mathematical symbols, modeling/simulation, and technological tools, such as computers and calculators. (Wiest et al., 2007, p. 48)

Finally, Wiest and her colleagues were also careful to observe that *questioning* is at the heart of effective numeracy: "Quantitatively literate individuals know what questions to ask, such as how data are collected, analyzed, and used" (p. 48).

A similar picture of basic mathematics can be found in *Principles and Standards for School Mathematics* (2000), the landmark guide published by the National Council of Teachers of Mathematics (NCTM). In this source, which is a handbook on the "reform" vision of mathematics and a source widely referenced in current scholarship (and nearly universally referenced in the articles consulted here for my ILP), the NCTM elucidated a set of ten standards that constitute the backbone of fundamental mathematical competence. The standards "describe a connected body of mathematical understandings and competencies—a comprehensive foundation recommended for all students" (NCTM, 2000, p. 29). Five of these standards are related to mathematical *content*: number and operations, algebra, geometry, measurement, and data analysis and probability. The other five are related to mathematical *processes*: problem solving, reasoning and proof, communication, connections, and representation. According to the NCTM, these ten ambitious standards "are required to achieve a society that has the capability to think and reason mathematically and a useful base of mathematical knowledge and skills" (p. 29).

Steen (2007), a well-known champion of mathematical literacy, provided some specific examples of skills that embody standards like those described by the NCTM and that make up an essential foundation in math. To Steen, *context* is of paramount importance in quantitative thinking and learning. Numeracy is "contextual mathematics" (p. 20) and consists of tools and competencies that are operational in at least three important contexts: civil society, the marketplace, and the workplace. In other words, effective education in numeracy skills renders students alert citizens, careful consumers, and competent workers. Steen suggested that quantitative literacy thus includes specific capacities such as being able to understand "how small samples can accurately predict public opinion, as well as how sampling bias can distort results"; being able to "estimate the long-term costs of making very low monthly credit card payments" or to "interpret conflicting reports of medical studies"; and being able to "review budgets and identify relevant trends" or to "develop a schedule to improve work flow on a complicated project" (p. 19).

Taking a more general approach than Steen, Wagner and Davis (2010) argued for an enhanced *quantity sense* related to but distinct from computation-based *number sense*. They acknowledged that "number permeates the existences of citizens of the modern, Western world" (p. 39), but suggested that number sense and quantity sense are too often conflated in curricula (including curricula based on the NCTM standards) and "within this conflation, calculations are strongly privileged" (p. 41). Skills in abstract numerical computation, in other words, tend to trump capacities for understanding what number sizes actually *mean*. For Wagner and Davis, it is just as important for students to develop a quantity sense—"a sense of *how much, size;* a *feel* for amounts and magnitudes" (p. 41). To this end, they developed and communicated three teaching strategies to promote students' deeper feeling for numbers of increasing orders of magnitude (under 100, 100 to 10,000, and greater than 10,000, respectively). A deeper sense of

quantity among students would "enable them to interpret and respond critically to the barrage of numbers that they meet each and every day" (p. 48).

Best (2008) placed even greater emphasis on the importance of critical thinking as an essential aspect of numeracy. Like Wagner and Davis, Best argued that most current mathematics classes emphasize calculation skills and that quantitative literacy "needs to move beyond calculation" (p. 125). For Best, though, this entails helping students "to understand the social processes that shape the creation and consumption of statistics about public issues" (p. 125). Students encounter numbers everyday—numbers that are designed by various sources not only to inform, but also to influence. Therefore, according to Best, quantitative literacy necessarily implies the development of students' capacities to think clearly and critically about how and why such numbers are constructed:

> Students need to learn to think critically about these numbers, and this requires more than having a sense of how those numbers were calculated. Students also need to understand these statistics as the results of social and political, as well as mathematical, processes. And this requires confronting matters of construction. (Best, 2008, p. 128)

Finally, D'Ambrosio (2007) expanded the vision of quantitative reasoning by proposing a "new concept of curriculum, synthesized in three strands": literacy, *matheracy*, and *technoracy* (p. 28). For D'Ambrosio, the communicative aspects of quantitative reasoning—namely, basic skills in counting, calculating and measuring as well as the interpretation of graphs, tables and statistics—fall under the first strand of literacy (p. 29). This is because those numerical and graphical skills are essentially related to "the capability of processing information" (p. 29), or *reading* in its broadest sense. Matheracy, the second strand, involves deeper reflection since it "is the capability of inferring, proposing hypotheses, and drawing conclusions from data" (p. 29). And the third strand is technoracy or a "critical familiarity with technology" (p. 29).

Synthesizing these views, therefore, it seems that quantitative literacy involves a contextual proficiency with mathematical content and processes by combining a basic set of skills with a critical awareness of the relevance of mathematical patterns in the world. It is important to note here that quantitative literacy thus conceived is central not only to humane mathematics education, but also to the broader movement of humane education. For according to Weil (2004), the first two essential components of humane education include the provision of accurate information "so students understand the consequences of their decisions as consumers and citizens" (p. 19) and the fostering of critical thinking "so students can evaluate information and solve problems" (p. 19). These elements resonate strongly with the reasoning skills and critical capacities already mentioned as central to an effective quantitative literacy.

But *why* should students be required to achieve quantitative literacy? Some answers to this question have already been suggested here—specifically regarding the importance of critical thinking as a valid end in itself (see especially Best, 2008; Wagner & Davis, 2010; Weil, 2004). But scholars cite additional motivations as well. One reason that quantitative literacy is valued is because it is of *personal* importance to students. The contemporary world is such that individual students cannot cope effectively in their own lives without numeracy: "Because analysis and argument in so many areas of life now make use of numerical data, it is no longer possible to be literate without also being numerate" (Steen, 2007, p. 18). Put another way, since "the underpinnings of everyday life are increasingly mathematical and technological," a fundamental knowledge of mathematics "can be personally satisfying and empowering" (NCTM, 2000, p. 4). And QL "fosters the types of essential mathematics skills and thinking . . . needed to live a more informed, proactive life" (Wiest et al., 2007, p. 47).

There are also various *social* dimensions driving the advocacy of quantitative literacy. Indeed, Best's (2008) emphasis on critical thinking within QL is largely motivated by the fact

that so much of the flood of information presented to students today is communicated by way of "figures that appear in discussions of public issues" (p. 133). The NCTM (2000) pointed out the importance of mathematics in various professional settings, in the scientific and technical communities, and more generally as a key part of human cultural achievement and heritage (p. 4). But even more than this, quantitative literacy and its learning involves issues of global citizenship and full access to the same. According to D'Ambrosio (2007), the three strands of his proposed new concept of mathematics curriculum "together constitute what is essential for citizenship in a world moving swiftly toward a planetary civilization" (p. 29). Wiest et al. (2007) specified some of the key issues: "Individuals lacking requisite quantitative literacy skills are impacted in at least three areas: economic access, civic participation, and decisions for their personal life" (p. 50). In other words, the marginalization of certain individuals and societal groups is at least in part due to disparities in numeracy education. Therefore,

> Quantitative literacy can address issues of social justice in at least two ways. Quantitatively literate individuals are better prepared to address inequitable societal situations, and they can improve their own life quality. In both cases they acquire and exert greater personal power to forge a better life, in the first case collectively for all people and in the second, individually, for themselves and their families. (Wiest et al., 2007, p. 47)

Ultimately, then, what is at stake with quantitative literacy is nothing less than positive social change on a planetary scale. And not only social change: the benefits of a substantial QL can of course be extended to involve responsibility for and positive change on behalf of nonhuman animals and the natural environment, because students' capacities to understand, produce, and think critically about quantitative information apply equally well in those contexts. In short, effective QL is beneficial not only for learners—it is also good for the world.

Contributions of Mathematics to Current Educational Discourse

With the potential benefits of effective numeracy in mind, it may now be helpful to continue this line of investigation by exploring the question of what exactly mathematics education can offer to critical current conversations about issues of culture, nonhuman animals, and the environment. What can mathematics provide students and teachers as they engage these conversations? In particular, can an excellent education in mathematics help to make all learners more compassionate in their thinking and acting? It is clear from the sources already discussed that many researchers and educators believe in the potential of mathematics education to enhance the practice of compassion among its learners. Along the spectrum from the relatively "conservative" reform approach (NCTM, 2000) to the more "radical" pedagogies for social justice (Gutstein, 2006, 2007; Lesser, 2007; Stocker, 2008; Wiest et al., 2007), many of those involved in mathematics education are working to improve on what they see as the limitations of traditional school mathematics.

Moreover, evidence reviewed in the first two sections above suggests that one of the most effective and powerful contributions math education can offer is the very *transformation of itself* in accordance with a vision of global justice. That is, there is a strong call for mathematics education to undergo a radical change in its own discourse and delivery in order to remain not only relevant but also beneficial in today's world. What I would like to explore more deeply in this third section, therefore, are some ideas regarding the nature and process of this transformation of math education.

Gutiérrez (2009) suggested that a deep transformation of mathematics education can occur only if math educators undertake a critical examination of their own terms of discourse. In particular, she warned against the prevailing focus on the "achievement gap" in the United States: "Although mainly concerned with the well-being of marginalized students, mathematics

education researchers who focus on the achievement gap can unknowingly support practices that are against the best interests of the students" (p. 9). The predominant gaze on the gap, according to Gutiérrez, drastically limits the conversation in math education to issues of "standardized test scores and the kinds of students who are capable of doing well in mathematics" (p. 10). To break out of this limited and limiting gaze, Gutiérrez, a mathematics teacher educator herself, argued for the need to "shift the conversation in teacher education away from the achievement gap to one that more easily exposes complex issues of identity and power" (p. 10). She described the complex work of "developing a pedagogy that both helps one's students *play* the game and *change* the game" of mathematics (p. 12), and then discussed her experience and belief in foregrounding three specific tensions or paradoxes in teaching mathematics. These tensions "surround the idea that an equity stance means: 1) knowing your students and not knowing them; 2) being in charge of the classroom and not being in charge of the classroom; and 3) teaching mathematics and not teaching mathematics" (p. 12). Gutiérrez claimed that the exploration of such tensions is "useful in developing in teachers a 'stance' on teaching that addresses identity and power issues" (p. 12).

In learning to embrace such paradoxes in both theoretical and practical work, teachers of mathematics become better "at dealing with the complexities that arise in teaching when transformation of society, not mere 'student achievement,' is the goal" (Gutiérrez, 2009, p. 15). This emphasis on the importance of tension or paradox in authentic education echoes both Palmer (1998, 2007) and Schumacher (1973). According to Palmer,

> Teaching and learning require a higher degree of awareness than we ordinarily possess—and awareness is always heightened when we are caught in a creative tension. Paradox is another name for that tension, a way of holding opposites together that creates an electric

> charge that keeps us awake. Not all good teachers use the same technique, but whatever technique they use, good teachers always find ways to induce this creative tension. (p. 76)

Like Gutiérrez, Nolan (2009) also pointed to the need for a shift in the prevailing discourse in mathematics education to allow for greater complexity. Specifically, Nolan advocated for greater care and deliberation in the face of "the current push to marry off mathematics with social justice" (p. 206). She criticized the prevailing frameworks for incorporating social justice concerns in math courses, including those frameworks utilized by Gutstein (2006, 2007) and Stocker (2008). To Nolan, the prevalent approaches are in fact too simplified (p. 207) and tend to gloss over the complexities of what she described as "two burning questions": "*What is social justice?* and, in the particular context of mathematics education, *How does (or, can) mathematics look and act when viewed in and through the lenses of social justice?*" (p. 206). Nolan's suggestion is, again like that of Gutiérrez (2009), to introduce a more critical examination—a deconstruction—of the pertinent discourse in the process of mathematics teacher education. Nolan used her own experiences as a teacher educator to support her calls for asking hard questions about curriculum, teaching, and the very nature(s) of math itself: "I believe that asking critical questions about these educational objects of our attention means questioning both the *content* with which we are charged to teach and the *context* in which we teach it, in accordance with our views on the nature of mathematics" (p. 210).

In other words, it is important for mathematics teachers-in-training to be exposed to radical conversations about what mathematics is and why it is taught, as well as about the ways in which it is taught: "A deconstructive reading of mathematics begins with the unchallenged suppositions about mathematics, and what counts as knowledge, and works backward to reveal its embedded injustices" (Nolan, 2009, p. 212). The marriage of mathematics and social justice is of paramount

importance to an educator like Nolan, and thus she emphasized examining that relationship with as much care and consciousness of complexity as possible:

> In mathematics teacher education, I am interested in working toward . . . an ideological shift—one that opens spaces of empowering possibilities and potentialities for prospective mathematics teachers and their students. . . . I continue to dream of a social justice-oriented mathematics classroom that begins by challenging the often invisible normative and regulatory aspects of schools and mathematics. (Nolan, 2009, p. 214)

Working from a similar respect for the normative and regulatory influence of mathematics education, D'Ambrosio (2007) advocated a heightened awareness of the *responsibilities* inherent in teaching and learning mathematics. Put succinctly, "mathematicians and math educators must accept, as priority, the pursuit of a civilization with dignity for all, in which inequity, arrogance and bigotry have no place" (D'Ambrosio, 2007, p. 25). For D'Ambrosio, "survival with dignity" (p. 25) is the pressing problem of the day; therefore, "our major responsibility, as mathematicians and mathematics educators, is to offer venues of peace" (p. 27). How are such venues provided? First of all, they are based on a foundational ethics of diversity: "The essence of the ethics of diversity is respect for, solidarity with, and cooperation with the other (the different)" (p. 28). On such a basis is built the "new concept of curriculum" (p. 29) called *ethnomathematics*:

> The Program Ethnomathematics contributes to restoring cultural dignity and offers the intellectual tools for the exercise of citizenship. It enhances creativity, reinforces cultural self-respect, and offers a broad view of mankind [sic]. In everyday life, it is a system of knowledge that offers the possibility of a more favorable and harmonious relation between humans and between humans and nature. (D'Ambrosio, 2007, p. 29)

This program, as D'Ambrosio envisioned it, issues forth in the three strands mentioned above (in the second section)—literacy, matheracy and technoracy.

The heart of what D'Ambrosio (2007) thinks mathematics and math education can offer the world is best captured in the two major reasons he gave for programming ethnomathematics into the curriculum. On the one hand, ethnomathematics can help "to de-mystify a form of knowledge [mathematics] as being final, permanent, absolute, unique" (p. 33). On the other hand, ethnomathematics can also "illustrate intellectual achievement of various civilizations, cultures, peoples, professions, gender" (p. 34). These two reasons comprise D'Ambrosio's proposal of new directions in thinking about mathematics and math education, "directions to counteract ingrained practices" (p. 28). Just like Gutiérrez (2009) and Nolan (2009), D'Ambrosio framed this proposal as a self-critical re-examination of the very terms of discourse in mathematics and math education—of the *what, how,* and *why* of teaching and learning mathematics. And also like Gutiérrez and Nolan, D'Ambrosio understood such a proposal as "the major challenge of educators, particularly mathematics educators" (p. 28).

Conclusions and Starting Points

The three topics of inquiry discussed in this chapter provide some insight into how much has already been pioneered and suggested in the realm of humane mathematics, as well as into how much remains to be critically examined and further developed. Though variant in many details, the scholarship underscores the view that a transformed and transformational mathematics—modeled and learned as a globally responsible, relevant and compassionate numeracy—does in fact have the potential to effect positive change for teachers and learners and their world. The important insights of the scholarship reviewed here will certainly influence and guide the development of the modules of my ILP, both in terms of the content of the mathematics concepts offered (theory) and the context of its delivery or experience (practice), and on behalf of all learners—both teachers and students. And so *Mathematics for a Broken, Beautiful World* ought to

be viewed, on its modest scale, as a contribution to the field of humane mathematics and to the creation of changes for the better in and through mathematics education.

Mathematics for a broken, beautiful world

A modular resource package for late secondary and early post-secondary math educators

• Table of Contents •

• INTRODUCTION •

1. Motivation

"When are we ever going to need to *use* this stuff?" Students of mathematics, including many of my own, routinely ask this question—and not without justification. It is indeed a sad fact that much of today's school mathematics is essentially disconnected from the realities of students' lives. Math is too often experienced as fundamentally irrelevant to the concerns of students as individuals and citizens in today's world.

This disconnection is particularly disappointing because mathematics is, in fact, as important today as it ever was. It forms a key conceptual toolset and an indispensable complex of insights that help us as human beings to make good sense of the conditions in which we live and the potentials to which we can aspire. The myriad and complicated challenges of our times cannot be fully appreciated or adequately approached by students unless they have at least a basic grounding in quantitative reasoning. Indeed, mathematics is *increasingly* essential to critical thinking about and effective action within a world in crisis.

Thus it is with a deep desire to properly *reconnect* mathematics with students' lives and concerns that I offer this project to mathematics educators. It is my belief that a mathematics passionately and deeply communicated can empower students to become creative and positive change-makers in the world they inherit.

2. Project Goals

The overarching goal of "Mathematics for a Broken, Beautiful World" is to further develop the new and emerging practice of *humane mathematics education*. In shortest summary, humane mathematics is math teaching and learning that is explicitly designed to guide students to become both competent and compassionate—*to make good sense of and make good change in their world*. My project in humane mathematics here is largely inspired by the broader movement of humane education as developed by Zoe Weil (2004) and others. Humane education, and thus its "subset" of humane mathematics education, strives to weave together four strands: the provision of accurate information about important issues;

the fostering of curiosity, creativity, and critical thinking; the instilling of reverence, respect, and responsibility; and the supplying of positive choices for ongoing learning and action.

"Mathematics for a Broken, Beautiful World" is also guided by the work of a number of contemporary mathematicians and mathematics educators who are exploring the various ways in which math education can help students become more compassionate global citizens. Among this group of humane mathematics pioneers are Rico Gutstein (2006, 2007), Ubiratan D'Ambrosio (2007), David Stocker (2008), Bob Moses (2002), Rob Root (2009), Jo Boaler (2006), Kathleen Nolan (2009), and Rochelle Gutiérrez (2009). I am pleased to contribute in a humble way to the positive movement that such remarkable figures have begun.

My project specifically targets mathematics educators working at late secondary (grades 11 and 12) and early post-secondary (first-year college or university) levels and who are teaching primarily within a North American context. The project aims to provide those teachers and their students with an enhanced understanding of some of the key numerical or quantitative characteristics of pressing contemporary issues. The mathematical elements of the project are communicated with a view to helping teachers and students to deepen their practices of compassion vis-à-vis other people, nonhuman animals, and the environment.

In concrete terms, "Mathematics for a Broken, Beautiful World" represents a *modular resource package* designed for educators of late secondary and early post-secondary levels. The package includes three major modules—key topic areas commonly found in mathematics curricula worldwide: basic probability theory, financial mathematics, and the study of rates of change (up to and including differential calculus). The structure and components of each module are designed to help mathematics educators encourage their students to pursue their own mathematics "problems"—that is, questions that involve quantitative reasoning and that are relevant to students' own lives and to the other people, nonhuman animals and natural environments that surround them. The module lessons aim to empower educators to help students take active and leading roles in mathematical investigations of some of the complexities of the modern world.

3. Design

The three modules share a similar basic design. Each module is introduced by way of a current and authentic news story or actual account that inspires attention and helps to render the mathematics "real" for both educators and learners. Next are pages outlining the

student learning objectives for the module, any conceptual prerequisites or assumed knowledge, and the procedure of activities that comprise the primary modular lesson. Each lesson explores a major conceptual principle from that module's mathematical topic area and is designed to be flexible in length and easily adaptable to various teaching contexts and constraints. Any pertinent activity sheets and instructor guides for the primary lesson are included. After the procedure outline is a list of helpful resources as well as suggested ideas for extensions of the primary lesson and "action options" that teachers and students could undertake in their specific locales. Finally, each module concludes with a reminder of the major question(s) that originally motivated the lesson and that can continue to inspire investigation and learning for teachers and students.

The materials referenced and utilized in the modules are chosen in an attempt to compile recent, accessible, and balanced research into contemporary issues of importance. And wherever possible and appropriate, information from diverse perspectives and multiple viewpoints is incorporated into the modular lessons.

4. Assessment

Though they do not include any traditional assessment components like quizzes or tests, the modules herein are designed to be easily incorporated into courses that may employ such standard forms of assessment. Moreover, the modules *do* provide educators with the opportunity to assess student learning objectives in at least three ways: First, the modular lesson activities and activity sheets require demonstration of mastery of the key math concept(s) within each module and could be periodically checked and/or collected at the teacher's discretion. Second, the modular lessons all require a certain amount of group work from students, and an observant teacher/facilitator could gauge learning outcomes in that context as well. And third, each primary modular lesson procedure concludes with a written reflection component that helps to reveal how deeply and how well and each student has engaged the mathematical and issue-related concepts involved in the module.

• MODULE 1 •
Probability Theory
"Risky Business"

•

Margaret and Kevin Curole are Cajun shrimpers in New Orleans, Louisiana. They have lived along the bayous all their lives and have experienced firsthand the crash of their local shrimping industry in the years since 2000. They were dealt another huge blow in April of 2010 when the British Petroleum-owned Macondo well ruptured in the Gulf of Mexico and 5 million barrels of crude oil were released into the sea.

Margaret claims that widespread mainstream media reports of the successful cleanup of the spill are simply wrong. "Here's the truth," she says. "Where are the animals? There's no too-da-loos, the little one-armed fiddler crabs. Ya don't hear birds. From Amelia to Alabama, Kevin never saw a fish jump, never heard a bird sing. This is their nestin' season. Those babies, they're not goin' nowhere. We had a very small pod of sperm whales in the Gulf, nobody's seen 'em. Guys on the water say they died in the spill and their bodies were hacked up and taken away. BP and our government don't want nobody to see the bodies of dead sea mammals. Dolphins are choking on the surface. Fish are swimming in circles, gasping. It's ugly, I'm tellin' you. And nobody's talkin' about it. You're not hearing nothin' about it. As far as the media is reportin', everythin's been cleaned up and it's not a problem. But you know what, unless I know where my fish is coming from, I'm eatin' nothin' from here" (Williams, 2010).

Given that human demand for energy continues to grow and that more and more "unconventional" fossil fuel reserves are being tapped to meet that demand, it is necessary to investigate and try to quantify the potential ecological and social dangers—like the BP spill in the Gulf of Mexico—of such projects. In other words, when it comes to extractive industries, *what* exactly are the risks we take, and *why* do we seem to be so willing to take them? What makes us entertain such *risky business*?

A. Module 1 Objectives

In this module, students will be able to:

- calculate basic probabilities pertinent to ecological and human-health concerns of industrial oil sands development in Canada
- engage in active research of statistical data concerning the industrial development of Canadian oil sands
- produce a risk assessment and action plan presentation based on the aforementioned research

B. Module 1 Materials

- copies of the student handout "Developing the Oil Sands"
- instructor's reference/key for "Developing the Oil Sands"
- calculator and/or computer for each student
- copies of student "Reflections" handout

C. Module 1 Prerequisites/Assumed Knowledge

Students should already be comfortable with the basic concept of the *probability* of an event in a sample space and should be able to express probabilities in fractional, decimal, and/or percentage form. Students should also be capable of recognizing *conditional probabilities* and should be able to employ the *union* and *product* rules of probability. Students who undertake either the Fort Chipewyan or the polling extension should understand the implications of *confidence intervals* in statistical research.

D. Module 1 Procedures

- Begin by introducing the idea of assessing the risk that accompanies the issues of global energy dependence and intensive resource extraction, perhaps by reading aloud the opening story about Margaret and Kevin Curole and the 2010 Gulf spill. Emphasize that the assessment of such risk involves the consideration of

both the *probability* of potential harm and the *severity* of it, components which can be in large part understood by quantitative methods of analysis.

- More specifically, now, introduce the controversial development of the bituminous Canadian oil sands or "tar sands" as the primary focus of the module. Use the following quotation from an article about oil sands development to establish the context: *"There is a huge market for fossil fuels and Canada's tar sands are promoted as a source that is safe from conflict and a far less risky venture environmentally than deep ocean drilling. At a time when conflict in the Middle East and the recent explosion in the Gulf of Mexico make those sources of oil unstable and unpopular, there is much interest and potential profit in piping synthetic crude out of Northern Alberta into existing markets in the United States and emerging ones in China"* (Stratton, 2010). Tell students that they will be undertaking an intensive process of investigation into this pressing global issue of industrial development of the Canadian oil sands.

- Distribute a copy of the "Developing the Oil Sands" worksheet to each student and review the worksheet with the entire class. The worksheet requires some preliminary practice with calculating probabilities that are directly and indirectly related to the oil sands, followed by a research project and presentation. Ultimately each individual or small group of students is asked to produce a risk assessment and community action plan based on a semi-fictional scenario (see the worksheet itself for specific details).

- Preview the entire worksheet with all of the students in your class/group so that they are clear about the expectations for each of the three parts. Concerning the third part of the worksheet—the research and presentation portion—emphasize that the three listed sources are the *minimum* requirement for their research. Individual students or groups may feel free to do more research, but they need at least to consult those three sources.

- The three listed research sources are all available online (and web addresses are provided), but you may wish to provide students with print versions as well or instead. You may also wish to point out to students the "partisanship" of each of

the articles: The *National Geographic* article represents a fairly balanced and journalistic approach, the second source is a pamphlet produced and published by industrial interests, and the third item is a fact sheet written by an active environmental conservation organization. All three sources are loaded with numerical data (statistics and probabilities) to illustrate and/or support their respective arguments, and it is this data that students ought to be on the lookout for in their reading and research.

- Depending on course format and schedule availability, determine an appropriate deadline for the submission of written presentations and a good time for the delivery of any oral/a-v presentations.

- After all of the presentations have been completed and submitted, close the module by showing the full class/group a short (20-minute) and passionate video talk that was delivered in December 2010 by author and activist Naomi Klein. You can find and play the video at the following web address: http://www.ted.com/talks/naomi_klein_addicted_to_risk.html. This video is especially pertinent as it focuses on *risk* and brings the module full circle by tying the BP oil spill back to the development of the oil sands. (Alternatively, because the video connects the Gulf spill to the tar sands, it could instead be shown at the *beginning* of the modular lesson to pique the interest of students and to more fully contextualize the activities.)

- Finally, distribute a "Reflections" handout to each student and provide some time for individual written responses.

- In addition to pursuing the resources and extensions listed at the end of the module, students could be encouraged to follow up on any practical action ideas that may have emerged from their research and presentations.

Risky Business

DEVELOPING THE OIL SANDS

Some Exercises and Considerations . . .

1. How Do Canadians Feel About the Sands?

- A recent poll (Ipsos Reid, 2010) showed that Canadians are fairly evenly split in their opinions about developing the oil sands of Alberta. The poll reported that slightly more than half of Canadians (51%) believe that the need for energy sources outweighs the risks of oil sands development, while the other near-half (49%) believe oppositely, that the environmental risks outweigh the need for energy.

- Also according to the poll, a majority of Canadians (70%) have heard *something* about the oil sands development, while the rest (30%) report that they have not. Among those who have heard something about the sands, almost one half (46%) thinks the development is a "good thing," nearly one-third (32%) thinks it is a "bad thing," and nearly one quarter (22%) is indifferent.

- Using the information from the poll, determine the following probabilities:

    a. What are the chances that a randomly chosen Canadian has heard something about the oil sands and thinks the development of them is a good thing?

    b. What is the probability that a randomly chosen Canadian has heard something about the oil sands and thinks the development of them is a bad thing?

    c. What are the chances that a randomly chosen Canadian has heard something about the oil sands and is indifferent to the development of them?

    d. What is the probability that a randomly chosen Canadian has not heard about oil sands development or has heard something and is indifferent?

2. Cancer Cluster in Fort Chipewyan

- Fort Chipewyan or "Fort Chip" is a small community of about 1200 people, most of them First Nations or Métis, located on the Athabasca River downstream from the largest industrial activity on the oil sands.

- In 2006, the doctor serving Fort Chip, John O'Connor, publicly reported what he believed was an unusually high occurrence of cholangiocarcinoma in the community. Cholangiocarcinoma is a rare and painful cancer of the bile duct that normally (worldwide) afflicts one in about 100,000 people. Dr. O'Connor reported having seen *five* different cases of the cancer in Fort Chip over the course of a few years serving the community.

- If you were Dr. O'Connor, how many cases of cholangiocarcinoma would you have expected to find in Fort Chip? (In other words, assuming a normal rate of occurrence, what was the probability of discovering that type of cancer in Fort Chip?)

- Consider what you would have done and/or said if you had been Dr. O'Connor—or what you might have been curious about after making such a discovery.

3. Risk Assessment and Community Action Plan

- For this component, you will be working on an extensive research and presentation project. You may work individually or with one or two partners of your choice (maximum group size is three). Please read all of the details of the project before choosing your partner(s).

- You and any partner(s) represent the town council of a small community in the oil sands region of Alberta, Canada. Your town's population consists primarily of people of aboriginal descent who have long-standing historical ties to the local land.

- Your town has been approached by a large oil company that is interested in developing the oil sands that fall within the geographical reaches and legal jurisdiction of the town. The company is interested in leasing the town's land for industrial development that will include open-pit mining, in situ bitumen extraction, tailings pond construction, and pipeline oil transport.

- You and your partner(s) need to undertake research into the typical nature and pace of contemporary oil sands development and the various potential consequences that such development entails. Your research will include but need not be limited to the following three sources:

a. "The Canadian Oil Boom," an article by Robert Kunzig in the March 2009 issue of *National Geographic*. You can access the article at the following web address: http://ngm.nationalgeographic.com/2009/03/canadian-oil-sands/kunzig-text

b. "The Facts on Oil Sands 2010," a pamphlet published by the Canadian Association of Petroleum Producers. You can download the pamphlet at http://www.capp.ca/UpstreamDialogue/OilSands

c. "Canada's Tar Sands," a fact sheet produced in 2008 by the International Boreal Conservation Campaign. You can find the fact sheet at http://www.borealbirds.org/resources/factsheet-ibcc-tarsands.pdf

- After completing your research, you and your partner(s) will need to formulate a risk assessment for your community and propose a community action plan in response to the interest and offer expressed by the oil company. You may present your assessment and plan in either of two formats:

  a. 10-15 minute oral/audiovisual presentation
  or
  b. 5-7 page written document

- Your group's risk assessment and action plan should communicate what you believe to be the most important considerations in weighing the potential benefits of development against the risks incurred. Specifically, you should report on what facts and statistics (and their sources) that your group found to be the most convincing and why. Then you should describe what you have decided to *do* as representatives of your town council.

Risky Business

Instructor's Reference/Key

DEVELOPING THE OIL SANDS

Some Exercises and Considerations . . .

1. How Do Canadians Feel About the Sands?

- A recent poll (Ipsos Reid, 2010) showed that Canadians are fairly evenly split in their opinions about developing the oil sands of Alberta. The poll reported that slightly more than half of Canadians (51%) believe that the need for energy sources outweighs the risks of oil sands development, while the other near-half (49%) believe oppositely, that the environmental risks outweigh the need for energy.

- Also according to the poll, a majority of Canadians (70%) have heard *something* about the oil sands development, while the rest (30%) report that they have not. Among those who have heard something about the sands, almost one half (46%) thinks the development is a "good thing," nearly one-third (32%) thinks it is a "bad thing," and nearly one quarter (22%) is indifferent.

- Using the information from the poll, determine the following probabilities:

    a. What are the chances that a randomly chosen Canadian has heard something about the oil sands and thinks the development of them is a good thing?

$0.7 \times 0.46 = 0.322 = 32.2\%$ **chance (product rule; conditional probability)**

    b. What is the probability that a randomly chosen Canadian has heard something about the oil sands and thinks the development of them is a bad thing?

$0.7 \times 0.32 = 0.224 = 22.4\%$ **probability (product rule; conditional probability)**

    c. What are the chances that a randomly chosen Canadian has heard something about the oil sands and is indifferent to the development of them?

$0.7 \times 0.22 = 0.154 = 15.4\%$ **chance (product rule; conditional probability)**

d. What is the probability that a randomly chosen Canadian has not heard about oil sands development or has heard something but is indifferent?

$0.30 + 0.154 = 0.454 = 45.4\%$ **probability or nearly half! (union rule)**

<u>Note</u>: A probability *tree diagram* may be a helpful format in which to frame the probabilities determined in parts a-d.

2. Cancer Cluster in Fort Chipewyan

- Fort Chipewyan or "Fort Chip" is a small community of about 1200 people, most of them First Nations or Métis, located on the Athabasca River downstream from the largest industrial activity on the oil sands.

- In 2006, the doctor serving Fort Chip, John O'Connor, publicly reported what he believed was an unusually high occurrence of cholangiocarcinoma in the community. Cholangiocarcinoma is a rare and painful cancer of the bile duct that normally (worldwide) afflicts one in about 100,000 people. Dr. O'Connor reported having seen *five* different cases of the cancer in Fort Chip over the course of a few years serving the community.

- If you were Dr. O'Connor, how many cases of cholangiocarcinoma would you have expected to find in Fort Chip? (In other words, assuming a normal rate of occurrence, what was the probability of discovering that type of cancer in Fort Chip?)

1 in 100,000 is proportional to 0.012 cases in a population of 1200 – so you would not have expected to find *any* cases of cholangiocarcinoma in Fort Chip (probability = 0).

- Consider what you would have done and/or said if you had been Dr. O'Connor—or what you might have been curious about after making such a discovery.

Risky Business

Reflections

In the space provided below, please respond to the following questions:

- **Now that you have done some research and produced a report, how do you feel about the nature and pace of industrial development in the Canadian oil sands?**
- **What influence, if any, does knowing some of the mathematics involved in oil sands development—in particular, the *probabilities* of various outcomes—have on your perspective?**

E. Module 1 Resources

- A comprehensive textual resource on oil sands development and its range of social, economic, and ecological implications is Andrew Nikiforuk's 2008 book *Tar Sands: Dirty Oil and the Future of a Continent* (Vancouver, BC, Canada: Greystone Books/David Suzuki Foundation). The opening section of this book, entitled "Declaration of a Political Emergency," is particularly direct and compelling and matches the urgent tone of the Klein video.

- David Suzuki, a Japanese-Canadian academic, journalist and environmental activist, produced a series of CBC radio programs on ecological issues that was broadcast in the summer of 2010 and entitled *The Bottom Line*. Two of the nine hour-long episodes in the series (episodes five and six) focus on the tar sands and feature interviews with a number of influential individuals involved in the tar sands development conversation. For more information and access to the audio for the pertinent episodes, visit http://www.cbc.ca/thebottomline/.

- The April 2010 issue of *New Internationalist* (NI 431) features a series of powerful articles and fact sheets dealing with the development of the tar sands and the various campaigns that are resisting that development. To access the issue, visit www.newint.org.

- The Pembina Institute is a 25-year-old sustainable energy think-tank and education organization with a major focus (and widely respected track record) on issues surrounding oil sands development. Learn about the institute and find links to publications and action areas by visiting http://www.pembina.org/ or www.oilsandswatch.org.

- At least three documentary films have been produced about the tar sands: *H2Oil*, *Dirty Oil*, and *Petropolis*. Any one of these films provides ample and astonishing visual imagery to communicate the incredible scale of oil sands development and impact.

F. Module 1 Extensions and Action Options

- Students could further investigate the story of the "cancer cluster" in Fort Chipewyan. Following Dr. John O'Connor's initial reporting of the cluster, a passionate controversy ensued in which the statistical data in question were discredited by some but upheld by others. Articles and other sources about the controversy abound (many of them available online), but a good start would be to read pages 88-92 in *Tar Sands* (Nikiforuk, 2008; see Resources).

- Students could research the statistical details of the 2010 Ipsos Reid poll of Canadians' feelings about oil sands development. The cited news release includes a description of the sample survey and its confidence interval.

- Bitumen extraction is widely viewed as a signature or symptom of peak oil. Students could explore the mathematics of the peak oil debate by investigating the probabilities represented by various peak oil forecasts and/or by researching Hubbert peak theory (which involves a logistic distribution model or curve).

- Students and teachers could engage the oil sands issue politically through "Tar Sands Watch," a campaign directed by the Polaris Institute, an organization devoted to supporting citizen-led movements for democratic social change. Find out more about the campaign at www.tarsandswatch.org.

- The Beaver Lake Cree are a Canadian First Nations people who have launched a legal challenge to halt oil sands development on their ancestral lands. For more information and to financially support the legal challenge, students could visit www.raventrust.com/projects/beaverlakecree.html.

G. Module 1 Burning Questions

Clearly and adequately weighing the risks alongside the potential benefits, *how* and *to what extent* should huge reserves of unconventional energy sources like the oil sands of Canada be rendered open to contemporary industrial development? What constitutes *acceptable risk* in such cases?

• MODULE 2 •
Financial Math
"What's the Deal with Debt?"

•

In 1974, Muhammad Yunus was a young professor of economics in Bangladesh. When a terrible famine overwhelmed the country that year, Yunus felt that the elegant economic theories he was teaching were increasingly meaningless in the face of the poverty and crushing hunger that he witnessed all around him. He wanted to do something more immediate, practical, and helpful—so he introduced himself to some of the neighbors in the village nearby his university campus. In a short time, Yunus met more than forty villagers who had fallen prey to the shady moneylending practices of some local "businessmen." With the equivalent of US $27 from his own pocket, Yunus freed the villagers from their crushing debtorship to the moneylenders and committed himself to helping the poor to get credit and fair loans.

In 1983, after years of failed attempts to convince local banks to change their lending and credit-granting practices, Yunus decided to create his own, separate bank for the poor. He called it Grameen Bank—"Village Bank." Since it opened, Grameen Bank has lent the astounding sum of US $6 billion in the form of collateral-free income-generating, housing, student, and micro-enterprise loans to poor families (primarily women). The bank's repayment rate has consistently been around 99 percent.

In 2006 Yunus and the founding members of Grameen Bank were awarded the Nobel Prize for Peace for their pioneering work, and today there are Grameen-type programs of microfinance in almost every country in the world (Yunus, 2007).

Given the recent global economic crisis, it is instructive to consider the major borrowing and lending structures that undergird human economic interactions. In particular, how do large-scale international lending practices compare to smaller-scale microcredit operations? In both cases we can ask: *What's the deal with debt?*

A. Module 2 Objectives

In this module, students will be able to:

- calculate a loan repayment size and complete an amortization schedule for two different lending scenarios
- compare the scales and details of two typical modern-day loan situations
- experience, through role-playing, some of the pressures and expectations faced by creditors and debtors within contemporary economic systems

B. Module 2 Materials

- copies of student role-play scenario handouts
- copies of amortization schedule worksheets for students
- instructor's references/keys for amortization schedules
- calculator and/or computer for each student
- copies of student "Reflections" handout

C. Module 2 Prerequisites/Assumed Knowledge

Students should already be comfortable with the concept of *compound interest* and should be aware of its prevalence in current economic systems. Students should be familiar with *annuities* and *amortization* and should be capable of calculating *schedules* for cases of the latter.

D. Module 2 Procedures

- Begin by introducing the issue of debt and credit, perhaps by reading aloud the opening story about Muhamad Yunus and the origins of Grameen Bank.

- Tell students that they will be participating in a role-playing exercise that consists of two "acts" and then time for reflection. In the first act they will be considering a large multilateral lending situation, and in the second act they will be exploring a microlending scenario. Inform the students that each group will proceed at its own

pace, and that when their group is finished with each portion of the exercise, they should check-in directly with the instructor/facilitator in order to continue.

- Split the class or large group into smaller groups of 3-4 students each. Distribute the "Role-Play Scenario #1" sheets to the members of each group. Give one member of each group an "IDB Lender" page (1★) and the remaining members of each group a "Government Representative from Haiti" page (1△). Ask the Haitian government representatives from all the groups to exit the classroom or activity space and to read through the scenario sheet once they are "outside." Ask the lenders from each group to remain in the classroom and, once the Haitian representatives have left, to occupy a position behind one of the desks or tables spread around the classroom and to wait for the other members of their group to approach them. Give each lender enough "Amortization Schedule #1" worksheets for themselves and the other members of their original group. Then instruct the lenders to read carefully through the scenario details. Return to the groups of Haitian representatives outside the classroom and make sure that the role-playing instructions are clear to all of them. To begin the exercise, open the doors to the classroom or activity area and tell each group of Haitian representatives to find its other original member—who represents a lending official from the Inter-American Development Bank (IDB). Now let the exercise unfold.

- Wander around among the groups, responding to any questions of clarification and sorting out any difficulties the group members may be having with their calculations. In particular, make sure to do an early check that each group has come up with the correct weekly payment size ($1,057,582.98—see the attached "Instructor's Reference/Key" page for the first scenario).

- As each group completes the "first act" of the role-playing exercise, have its members rearrange themselves together around a desk or table in as close to a "round-table" formation as possible. Then distribute the "Role-Play Scenario #2" sheets. Give each prior IDB lender a copy of the "Lakota Funds Representative" page (2★) and each prior Haitian representative a copy of the "Spotted Eagle Circle Members" page (2△). In other words, the IDB lender from the first round becomes the fund representative in the second round, and

those who were Haitian officials in the first round become circle member borrowers in the second round. Provide enough "Amortization Schedule #2" worksheets for all members of the group and then give the group members time enough to read through the second role-play scenario and understand their new roles. Tell the group it may begin when all its members are ready.

- As in the first round of the exercise, wander among the groups through the second stage and help students sort out any role-related and/or mathematics-related difficulties. In particular, check with each group early in the second stage to make sure it is working with the correct semi-monthly payment size ($18—see the attached "Instructor's Reference/Key" page for the second scenario).

- As each group completes the second stage of role-playing, ask its members to take a few minutes (5-10) to discuss together any initial reactions, feelings or thoughts concerning the two scenarios. Then distribute a "Reflections" form to each student and provide some time for individual written responses.

- To conclude the exercise, tell the reconvened class or larger group of students that they were in fact role-playing actual historical scenarios and that there are "postscripts" to both stories:

    - As for Haiti, it suffered a terrible earthquake in January 2010. The country was forced to take out additional loans for the recovery effort and its overall multilateral debt rose to US $1.25 billion (!). After mounting pressure from non-governmental quarters of civil society, the IDB board cancelled Haiti's outstanding debt in March 2010 (Stewart, 2010; Inter-American Development Bank Group, 2011).

    - Roselyn Spotted Eagle repaid her first loan from Lakota Funds and successfully created Spotted Eagle Enterprises. She continued to work with Lakota Funds to expand her business and bought a catering van with their help in 2008. Since its inception, Spotted Eagle Enterprises has served local clients as well as clients from New York, Minnesota, and Switzerland. Moreover, operating her own business has allowed Spotted

Eagle to be a primary support to her family members, including a great-granddaughter (Lakota Funds, 2009).

What's the Deal with Debt?

ROLE-PLAY SCENARIO #1
1☆ -- IDB Lender

Who Are You? – Personal Profile

- You are a high-level representative of the Inter-American Development Bank (IDB).
- Your bank, the IDB, is based in Washington, D.C. and was established in 1959 primarily to support Latin American and Caribbean governments and state corporations with services that include grants and loans. The IDB is the largest multilateral source of financing for Latin American and the Caribbean region.
- You are an American university graduate with an undergraduate degree in business and a masters degree in political science.
- It is January 2009 and you are 37 years old.

What Are You Doing? – Role-Play Plan

- Government representatives from the country of Haiti have arrived at your offices in Washington to have a meeting with you regarding their financial relationship with the IDB.
- Haiti's representatives will ask you what their country currently owes the IDB in terms of debt accrued from loans taken out by successive Haitian government administrations. When they ask you this, you can report that as of now (January 2009), Haiti owes the IDB $475 million (in U.S. dollars) on loans incurred since the end of 2004.
- Tell the Haitian representatives that you have been authorized to offer them a 10-year amortization of their $475 million debt at a rate of 3% compounded weekly.
- Tell the Haitian representatives that you will prepare a sheet describing their weekly debt-service payment size and outlining the schedule for their first six weekly payments. Tell them that you would also like them to do the same, and then provide them with the extra amortization schedule worksheets.
- After you have finished determining Haiti's weekly payment size and making the amortization schedule, review it with the Haitian representatives to make sure they understand their weekly financial responsibilities to the IDB.
- Finally, thank the Haitian representatives for coming and kindly excuse them from your office.

What's the Deal with Debt?

ROLE-PLAY SCENARIO #1

1△ -- Government Representative from Haiti

Who Are You? – Personal Profile

- You are a government representative from Haiti, the Caribbean country directly east of Cuba.
- Haiti, the country of your birth, is the poorest country in the Americas according to the United Nations-sponsored Human Development Index. Your country has a long history of poverty and an equally long legacy of external debt.
- You and your colleagues represent Haiti's Ministry of Finance and Economy and have been in your positions for more than two years.
- It is January 2009 and you are 48 years old.

What Are You Doing? – Role-Play Plan

- You and your colleagues from the Ministry have traveled to Washington, D.C., for a meeting at the offices of the Inter-American Development Bank, or IDB. The IDB is Haiti's largest creditor (lender of loans and granter of grants) and you are meeting with an IDB official to discuss your country's financial standing with the bank.
- After introducing yourself and your colleagues, ask the IDB representative what amount Haiti currently owes the IDB in terms of debt accrued from loans.
- From this point forward please do what the IDB representative instructs.

AMORTIZATION SCHEDULE #1
for
the First Six (Weekly) Payments
of
Haiti's Debt to the Inter-American Development Bank

$$R = \frac{Pi}{1-(1+i)^{-n}}$$

Payment Number	Amount of Payment (R)	Interest for Period (i)	Portion Applied to Principal	Principal at End of Period (Balance)
0	---	---	---	
1				
2				
3				
4				
5				
6				

What's the Deal with Debt?

ROLE-PLAY SCENARIO #2
2☆ -- Lakota Funds Representative

Who Are You? – Personal Profile

- You are a Loan Portfolio Manager at Lakota Funds, a community-based financial institution with headquarters in Kyle, South Dakota, on the Pine Ridge Indian Reservation. Pine Ridge is the eighth largest reservation in the United States and has a long history of poverty.
- According to its mission statement, Lakota Funds is "leading an economic resurgence of the Oglala Lakota Oyate on the Pine Ridge Reservation through culturally appropriate strategies reigniting the traditional Lakota spirit of productivity, commerce, and trade."
- You are an enrolled member of the Oglala Sioux Tribe and a graduate of Oglala Lakota College. Your undergraduate degree was in social work and you have numerous certifications in finance.
- It is September 1991 and you are 37 years old.

What Are You Doing? – Role-Play Plan

- A few other members of your tribe have come to your office in Kyle to propose an idea for a small business venture. You are reviewing their application for a potential loan portfolio.
- Your visitors will introduce themselves and ask you if Lakota Funds can provide a small loan to help launch their venture. When they ask you this, you can report that you are authorized to offer them a loan of $400 (U.S. dollars).
- Tell your visitors that the loan needs to be repaid in 1 year at a rate of 15% compounded twice-monthly (in other words, compounded 24 times per year).
- Provide your visitors each with a copy of an amortization schedule. *Working together with them*, determine the twice-monthly loan repayment size and outline the schedule for the first six payments.
- Once you are confident that you and your visitors understand the loan repayment schedule, thank them for coming and kindly excuse them from your office.

What's the Deal with Debt?

ROLE-PLAY SCENARIO #2
2△ -- Spotted Eagle Circle Member

Who Are You? – Personal Profile

- You are a member of the Oglala Sioux Tribe and live on the Pine Ridge Indian Reservation in South Dakota. Pine Ridge is the eighth largest reservation in the United States and has a long history of poverty.
- You and your colleagues are all artisans and mothers. One of your group (to be chosen by the group now) is named Roselyn Spotted Eagle. Roselyn is an accomplished maker of beaded moccasins for pow-wow dancers.
- Your group is made up of long-time friends and is supportive of Roselyn's current efforts to launch a small moccasin-making business.
- It is September 1991 and you are 53 years old.

What Are You Doing? – Role-Play Plan

- You and your group have traveled across Pine Ridge for a meeting at the offices of Lakota Funds, a small lending institution on the reservation. You have gone to Lakota Funds to propose an idea for a small business venture—Spotted Eagle Enterprises.
- One member of your group, Roselyn Spotted Eagle, will introduce herself and the rest of the group to the Lakota Funds representative. Roselyn will explain to the representative that she is applying for a small start-up loan to help her buy materials for a moccasin-making business, and that the other members of the group have agreed to be her "banking circle" of support—to assist her in her business and in her assumption of the responsibilities for repaying the loan.
- After the introductions and loan request, your group will proceed according to the Lakota Funds representative's instructions.

AMORTIZATION SCHEDULE #2
for
the First Six (Semi-monthly) Payments
of
Roselyn Spotted Eagle's Debt to Lakota Funds

$$R = \frac{Pi}{1-(1+i)^{-n}}$$

Payment Number	Amount of Payment (R)	Interest for Period (i)	Portion Applied to Principal	Principal at End of Period (Balance)
0	---	---	---	
1				
2				
3				
4				
5				
6				

Instructor's Reference/Key

AMORTIZATION SCHEDULE #1
for
the First Six (Weekly) Payments
of
Haiti's Debt to the Inter-American Development Bank

$$R = \frac{Pi}{1-(1+i)^{-n}}$$

Payment Number	Amount of Payment (R)	Interest for Period (i)	Portion Applied to Principal	Principal at End of Period (Balance)
0	---	$i = \frac{0.03}{52}$	---	475,000,000
1	1,057,582.98	274,038.46	783,544.52	474,216,455.48
2	1,057,582.98	273,586.42	783,996.56	473,432,458.92
3	1,057,582.98	273,134.11	784,448.87	472,648,010.05
4	1,057,582.98	272,681.54	784,901.44	471,863,108.61
5	1,057,582.98	272,228.72	785,354.26	471,077,754.35
6	1,057,582.98	271,775.63	785,807.35	470,291,947.00

Instructor's Reference/Key

AMORTIZATION SCHEDULE #2
for
the First Six (Semi-monthly) Payments
of
Roselyn Spotted Eagle's Debt to Lakota Funds

$$R = \frac{Pi}{1-(1+i)^{-n}}$$

Payment Number	Amount of Payment (R)	Interest for Period (i)	Portion Applied to Principal	Principal at End of Period (Balance)
0	---	$i = \frac{0.15}{24} = 0.00625$	---	400.00
1	18.00	2.50	15.50	384.50
2	18.00	2.40	15.60	368.90
3	18.00	2.31	15.69	353.21
4	18.00	2.21	15.79	337.42
5	18.00	2.11	15.89	321.53
6	18.00	2.01	15.99	305.54

What's the Deal with Debt?

Reflections

In the space provided below, please respond to the following questions:

- **How did it feel to be in your position in each of the two role-playing scenarios? In particular, comment on any feelings of power and/or powerlessness.**
- **What influence, if any, did making sense of the mathematics involved (that is, the amortization schedules and payment sizes) have in your conversations and in your experience of your roles?**

E. Module 2 Resources

- For information on large international financial institutions (IFIs) like the World Bank and the International Monetary Fund, check out their home pages. For example, visit www.worldbank.org or www.imf.org.

- For an excellent critical perspective on the IFIs and multilateral lending, refer especially to "Getting Into Debt," a booklet published in June 2010 by the Jubilee Debt Campaign. You can access and download at the following site: www.jubileedebtcampaign.org.uk/gettingintodebt.

- Visit the Lakota Funds homepage at www.lakotafunds.org to read about Spotted Eagle Enterprises as well as many other ventures that this pioneering and successful North American microfinancial institution has sponsored.

- For a challenging recent discussion on microlending, read the *Globe and Mail* article about it that can be retrieved at the following address: http://www.theglobeandmail.com/news/world/microfinance-little-loans-big-trouble/article1797584/.

- For even more on the potentials of microfinance, or go to http://www.ted.com/talks/jessica_jackley_poverty_money_and_love.html and view a passionate and inspiring talk by Jessica Jackley, founder of Kiva.org, the world's first personal microlending website.

- Margaret Atwood's five-part 2008 CBC Radio Massey Lecture series *Payback: Debt and the Shadow Side of Wealth* presents a series of creative, insightful and challenging reflections on the meaning of debt in human culture. The final lecture is particularly pertinent to this module. A book version of *Payback* is also available (Toronto: House of Anansi Press, 2008).

F. Module 2 Extensions and Action Options

- Students could explore the uses of technology—in particular, spreadsheets—to complete the details of amortization schedules. They could thus more easily and quickly calculate the effects of changes in lending conditions such as periodic interest rate or payment size.

- Students could research the debt burdens of various countries and convene a "summit" to discuss the causes, effects, and principles of international debt.

- Students as well as teachers could actively participate in the international Jubilee Debt Campaign to cancel so-called "Third World" debt. Jubilee UK's homepage has extensive information on ways to get involved: www.jubileedebtcampaign.org.uk/.

- The Internet has greatly expanded the possibilities for individuals to access the benefits of microfinance. Anyone can visit www.kiva.org and instantly contribute to or apply for a microloan!

G. Module 2 Burning Questions

What financial principles and systems embody the most effective way to lend and borrow resources in order that individuals and communities can avoid/escape conditions of poverty and transform their world for the better?

• MODULE 3 •

Functions and Rates of Change

"A Gathering Crowd"

•

At the 2009 World Economic Forum in Davos, Switzerland, the then President of South Africa, Thabo Mbeki, spoke to the assembly about his dreams for the new South Africa—a South Africa where everyone enjoyed the ability to own cars, computers and television sets. From the floor came a response. Satish Kumar, activist and magazine editor, said to Mr. Mbeki, "If people in South Africa, Brazil, China, India and the rest of the world attempt to own personal computers, cars, TV sets and the latest fashion in clothes, like the Europeans and Americans do, then we will need the resources of three or four planets. Mr. President, we haven't got three or four planets; we have only one. Isn't it time for Europeans and Americans to free themselves from their obsession with fashion and consumer goods rather than Indians, Africans and Chinese aspiring to the wasteful Western lifestyle?"

After a few moments of reflection Mr. Mbeki replied, "We cannot turn the clock back to an egalitarian, pastoral past; we are in the age of technology, progress and development. We cannot allow our people not to enjoy the same comforts and conveniences which Europeans and Americans take for granted. I want to bring high living standards to our people in South Africa and I am sure governments in India and South America want to do the same. There are plenty of resources to go around!"

There was not time for Kumar and Mbeki to continue their conversation (Kumar, 2009).

Given that the human population of the planet is projected to reach 7 billion by late 2011 and 9 billion by 2045, and that more than 95% of this growth will likely happen in the less developed world (Kunzig, 2011), the questions raised and the worldviews represented in this brief exchange at Davos are urgent. What *is* the earth's true carrying capacity? Can the planet handle our *gathering crowd?*

A. Module 3 Objectives

In this module, students will be able to:

- describe and model human population growth during the past 600 years with an exponential function, considering both the total amount of growth and average and/or instantaneous rates of increase
- explain the strengths and limitations of modeling human population growth with an exponential function
- explore and discuss some of the environmental, cultural, and economic impacts of human population growth

B. Module 3 Materials

- copies of the student handout "World Population Milestones"
- calculator and/or computer for each student
- copies of student "Reflections" handout

C. Module 3 Prerequisites/Assumed Knowledge

Students should already be familiar with the concept of a *mathematical function* and should be aware of some of the major types of functions—linear, quadratic, exponential, etc. Students should also be comfortable *graphing* functions by hand and/or with the help of technology. Students who will be determining the exponential function(s) themselves should know the basic rules of *logarithms*. And any students engaging the calculus extension should understand the concept of *instantaneous rate of change* and should be capable of finding the *derivative* of an exponential function.

D. Module 3 Procedures

- Begin by introducing the issue of human population growth, perhaps by reading aloud the opening story about Satish Kumar and Thabo Mbeki.

- Distribute the "World Population Milestones" table to students and invite them (individually or in small groups) to graph the data it contains, either by hand or with the help of technology.

- Discuss the nature of the graph and point out that it is a possible example of an exponential growth curve.

- Suggest to students that the data could be represented/modeled by an exponential function of the form $A(t) = A_0 e^{kt}$, with A_0 representing the "initial" population amount, t representing the number of years after the initial measurement, and k representing the constant of growth. Either provide students with this function or have them determine it themselves. Actual function models and corresponding k values will vary slightly according to the chosen A_0 and other selected data points. For example, letting $t = 0$ in 1930 and using 1999 as another point, the function is $A(t) = 2e^{0.0159t}$ (in billions). But other choices of initial values and second points will provide slightly different constants of growth. These variations could even be an additional topic for discussion.

- Now introduce the concept of rates of change in the human population, still using the data from the "World Population Milestones" table. Have students, again individually or in their same small groups, determine various *average* rates of change in population. For instance, the average rate of change in the human population between 1960 and 2010 was 3.8 billion in 50 years, or 76 million per year. Discuss whether or not such averages would represent an *actual* rate of change for a given year.

- Calculus extension: Students familiar with derivatives, or *instantaneous* rates of change, could determine the derivative of their exponential function model and then evaluate that derivative for various years. For example, the derivative of the function mentioned above would be expressed as $A'(t) = 0.0318e^{0.0159t}$ and so the instantaneous rate of change in population for the year 2010 would be $A'(80)$ or about 113 million people per year. Discuss the difference between such a rate and an average rate of change.

- Next invite students to use their exponential function models to project human population values into the future. For example, again with the function from above, the population projection for the year 2020 would be $A(90)$ or almost 8.4 billion. Have students consider the accuracy of such projections in light of any other factors that might affect growth rates. Tell them, for instance, that many demographers point to a current "slowing" in the growth rate (attributed largely to a decrease in the global fertility rate average) and that they do not expect the human population to reach the 8 billion mark until the year 2045 (Kunzig, 2011).

- Break students into small groups now (either their original ones or new ones) and invite them to brainstorm and discuss the various impacts of the human population growth that they have been modeling. One way to do this would be to ask each group to produce a concept map detailing the connections between human population increase and carrying-capacity issues such as food scarcity or urbanization. A vast number of connected issues will surface in such an activity, but the following key issues will likely emerge:

    - deforestation
    - impacts of grazing
    - industrial-scale farming and fishing
    - ocean health
    - food and water supply
    - climate change forecasts
    - the growth and multiplication of megacities
    - poverty reduction
    - human migration
    - education (especially for girls and women) and family planning
    - energy requirements
    - cultural diversity and rights of indigenous peoples
    - comparative conditions in "developed" and "developing" worlds

- After each group has had the opportunity to develop a concept map, reconvene the class as one group. Then facilitate a round-table discussion of some of the

issues that came forward in the small groups and/or attempt to link the concept maps together into a single class concept map.

- If desired, the concept-mapping activity could be introduced and/or accompanied by the reading of some textual material, perhaps something like the *National Geographic* feature article on population (Kunzig, 2011), the *Population Bulletin* from the Population Reference Bureau (PRB staff, 2010), or "The People Connection" article from Population Connection (2010).

- Finally, encourage students to record some of their feedback from the human population growth activities on the attached "Reflections" form.

A Gathering Crowd

World Population Milestones Table

Year	Estimated World Population
1400	350,000,000 (350 million)
1500	500,000,000
1600	545,000,000
1700	610,000,000
1800	1,000,000,000 (1 billion)
1900	1,600,000,000
1930	2,000,000,000
1960	3,000,000,000
1974	4,000,000,000
1987	5,000,000,000
1999	6,000,000,000
2000	6,100,000,000
2010	6,800,000,000
2011	7,000,000,000
?	8,000,000,000

Sources: Kunzig (2011)
Population Division of the UN (2009)
Population Reference Bureau (2010)

A Gathering Crowd

Reflections

In the space provided below, please respond to the following questions:

- **How do you feel about what you have learned concerning the current scale and magnitude of human population growth?**
- **What significance, if any, does your new knowledge of the mathematics involved in human population growth issues (that is, exponential growth and rates of change) have for you?**

E. Module 3 Resources

- The National Geographic Society is running a series of print, radio, and video stories throughout the year (2011) on population and it impacts. The opening piece in this series is a comprehensive report by Robert Kunzig in the January 2011 issue of *National Geographic* magazine.

- The Population Reference Bureau (PRB) is a Washington-based organization dedicated to informing and empowering people around population, health and environment issues. Their extensive website can be found at http://www.prb.org/.

- Population Connection (formerly known as Zero Population Growth) is another Washington-based group dedicated to education and empowerment on population issues. Check out the group's website at http://www.populationconnection.org/site/PageServer. This site has a running population clock, links to articles and activities connecting population growth to various sustainability issues, and a collection of great educational resources as part of the "World of 7 Billion" campaign.

- *Maybe One: A Case for Smaller Families* (New York: Penguin, 1998) is both a personal and scholarly reflection on population issues by writer and activist Bill McKibben. Though slightly dated, the three chapters that make up the second part of the book, "Species," are particularly pertinent to this module.

- Swedish statistician Hans Rosling has been a vocal and active researcher into issues of global development and population growth. Watch an insightful, brief (10 minutes) and challenging talk he delivered at a conference in 2010: http://www.ted.com/talks/hans_rosling_on_global_population_growth.html

- In Chapter 16 of his bestselling 2005 book *Collapse: How Societies Choose to Fail or Succeed* (New York: Viking), geographer Jared Diamond offers a list of the dozen most pressing problems facing past and present societies. The last two

problems, which are connected to all the others, both involve the increase in human population.

F. Module 3 Extensions and Action Options

- Using their findings from the rates of change segment of the lesson (average and/or instantaneous), students could enhance and demonstrate their facility with large numbers by converting annual growth rates (hundreds of millions per year, for example) to weekly, daily, hourly, minute-by-minute, or even second-by-second rates. In other words, students could determine their own "population clocks."

- Students could conduct inquiries into the sources of the data listed in the "World Population Milestones" table. Research into the gathering of statistical information like human population amounts could deepen their appreciation for the strengths *and* limitations of such numbers.

- Experienced calculus students could explore why and how a *logistic function* provides a more appropriate model for population than a basic exponential function, if the planet's carrying capacity is more explicitly known or assumed.

- Students could participate in personal and/or political activism through either the PRB or Population Connection websites (see "Resources" section above). In particular, students could get involved with actions that support girls' education and family planning initiatives around the world.

- Students and teachers could discover and consider their own ecological impacts on the planet by taking a "footprint" quiz. One such quiz is promoted by the Center for Sustainable Economy and can be accessed at http://myfootprint.org/en/. Participants are provided with instant results on the quiz as well as suggestions to reduce the scale of their personal impact.

G. Module 3 Burning Questions

Is human population growth threatening to overshoot and jeopardize the earth's carrying capacity? If so, what can be done about it?

• Ideas for other modules •

The modules included in this package are just three of many possible projects in humane mathematics education at the late secondary and early post-secondary levels. Here are some ideas for other modules:

- an *ethnomathematical* unit concerning, for example, the occurrence of fractal geometric design in indigenous African communities

- more on *rates of change* through an examination of widespread species extinction or the decline in human linguistic diversity

- a *statistical analysis* of polling and/or voting systems

- an investigation into various *mathematical models* of climate change

- an exploration of *linear programming* techniques through the context of chocolate and/or coffee production and fair trade policies

- a consideration of the law of diffusion of innovation and its *statistically normal* (bell curve) properties

- a module concerning the use of *probability* in public health strategies—for instance, in the context of screening for diseases like AIDS or cancer

- a project on the eight United Nations Millennium Development Goals (MDGs) and the *numerical benchmarks* they strive to establish

• Humane math resources •

There are a number of excellent resources available to assist educators in developing and enhancing both the theory and practice of humane mathematics education. Here are brief descriptions of a few of these resources:

- Eric (Rico) Gutstein is a leading figure in the humane mathematics movement, and his books and articles are excellent sources of wisdom and practical ideas. In particular, his 2006 book *Reading and Writing the World with Mathematics: Toward a Pedagogy for Social Justice* (New York: Routledge) is foundational.

- David Stocker's 2008 book *Maththatmatters: A Teacher Resource Linking Math and Social Justice* (2nd ed., Ottawa, ON, Canada: Canadian Centre for Policy Alternatives) is an award-winning collection of humane mathematics lessons. Although the lessons are targeted to middle school students, the introduction is pertinent and useful at all levels and the lessons provide an excellent sense of the "flavor" of humane mathematics in general.

- *Rethinking Mathematics: Teaching Social Justice by the Numbers*, a 2006 book edited by Eric Gutstein and Bob Peterson (Milwaukee: Rethinking Schools) is an excellent compendium of theoretical and practical wisdom. It contains numerous articles outlining basic principles (and experiences) of humane math education as well as a number of sample lesson ideas and a list of further resources.

- An interesting, accessible, and brief article highlighting some of the key elements and positive outcomes of successful humane mathematics education is Jo Boaler's "Urban Success: A Multidimensional Mathematics Approach with Equitable Outcomes" (from the January 2006 issue of *Phi Delta Kappan*).

- Finally, an excellent online resource for educators is "Radical Math" (www.radicalmath.org). This website was created and launched in 2006 by teacher Jonathan Osler and provides links to lesson plans, articles, data sets, news and events pertinent to humane mathematics educators.

• About the author •

Kurt Schmidt is an educator with deep concerns for other people, nonhuman animals, and the environment.

He has experience in tutoring and teaching mathematics at various levels (high school, community college and university) and in various geo-cultural contexts (Atlantic Canada, the United States, and Tanzania).

Kurt produced this modular resource package in partial completion of a master of education degree with a concentration in humane education.

Kurt's primary goals are to be

competent,

compassionate and

creative

in his learning and teaching.

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Chapter IV

Summary

I undertook this Independent Learning Project (ILP) in order to address what I perceive as a fundamental disconnection between much of present-day school mathematics and the actual experiences and concerns of mathematics students, especially at late secondary and early post-secondary levels. In the context of addressing that unfortunate and unnecessary disconnection, I strove to achieve four key goals: (1) to deepen my understanding of and contribution to the burgeoning field of humane mathematics, (2) to apply substantial mathematics to critical contemporary issues, with a view to inspiring compassionate responsive action, (3) to produce a modular resource package for educators to use in late secondary and early post-secondary mathematics courses, and (4) to empower educators and students through the modular resource package to pursue "real" mathematics and to make the pertinent questions and insights of mathematics their own. Chapter III of this ILP, "Mathematics for a Broken, Beautiful World," represents the concrete development of the modular resource package mentioned in the third and fourth goals.

I engaged in both scholarly and non-scholarly research in order to properly inform the development of the modular resource package. My scholarly research focused on three major areas: current exemplary practices in the field of humane math education, numeracy as a key component of responsible global citizenship, and the ways in which mathematics education can contribute to and positively influence current conversations about critical issues. As I had anticipated, the quantity and quality of available resources (academic articles) in these three areas turned out to be more than adequate for my research. I was also able to supplement this scholarly investigation with non-scholarly research that included web-based study, personal consultation with mathematics educators, and the piloting of some lesson components from the

modular resource package. Overall, my research efforts proved to be informational as well as inspirational.

As far as the process of research and production of "Mathematics for a Broken, Beautiful World" is concerned, I am pleased to report that I encountered no unforeseen obstacles or surprises in the course of the work. I was able to locate, access, and utilize excellent resources at every stage of the process. Moreover, it felt neither artificial nor "forced" to connect various mathematical topics and methods with important environmental and cultural issues. On the contrary, it seemed quite natural and straightforward to incorporate key insights and suggestions from my research into the design of the modular resource package. And I hope and trust that the package itself will turn out to match its intentions for educators and their students—to connect solid mathematical instruction with "real life."

Conclusions

So what exactly have I learned in the process of producing "Mathematics for a Broken, Beautiful World," and how will it influence my own teaching practice in the future? First of all, I was reconfirmed in the conclusion that both *content* and the *process* matter greatly (see especially Stocker, 2008) when it comes to providing pertinent and effective mathematics education (and *any* education, really). At nearly every stage of the research and writing of this ILP, I encountered an explicit and/or implicit emphasis on this salient point. Therefore, within the modular resource package I strove to be fully aware of *what* mathematical and non-mathematical concepts were being communicated as well as exactly *how* they were approached and dealt with. And in both contexts, I attempted to employ clear thinking, compassionate feeling, and creative activity.

Secondly, in designing the modules for the resource package, I discovered that in order for educators and students to achieve a deep understanding of the pertinent insights of

mathematics vis-à-vis pressing global issues, a strong foundation in reading and writing is a central requirement. This foundation includes capacities for basic reading comprehension as well as written analysis, interpretation and critical thinking. In other words, *numeracy* skills will only develop hand in hand with *literacy* skills, especially at late secondary and early post-secondary levels. A number of the sources from my scholarly research certainly pointed to this tandem relationship (especially Gutstein, 2006; Root, 2009; Steen, 2007). But I came to this conclusion also and primarily because of the significant reading and writing demands that I experienced *myself* in the process of developing the materials for the modules. It takes a good bit of essentially non-mathematical (or better, "co-mathematical") effort to uncover and sort out the mathematics that are more or less embedded in the issues of cultural and ecological importance that were chosen for the modular resource package. This required effort is necessarily passed along to students, and it manifests itself concretely in my ILP in some of the student activity sheets within the modular resource package—particularly in the oil sands worksheet from the first module and in the role-play scenario sheets from the second module, as well as in the reflection exercises in all of the modules.

Third, in the course of this ILP I was reminded of the ubiquity of technology as well as its potential helpfulness to students in their experiences of mathematics. Simply put, the math concepts tackled at late secondary and early post-secondary levels rely on a basic proficiency with calculators and/or computers. Key cultural and natural realities like compound interest and exponential growth are essentially inaccessible to students without some sort of fluency with calculating tools. Indeed, the increasing modern-day reliance—and in some cases, dependence—on electronic and digital technology is one of the reasons many educators point to the *growing* importance of mathematical understanding for their students (see, for example, NCTM, 2000; Steen, 2007). I would also like to note here that I certainly perceive the nature

and existence of the "digital divide" as an issue that is compelling and ripe *in itself* for humane mathematical exploration and action. But in the context of targeting my modular resource package for use by educators in North America, I went ahead and assumed wide, if not universal, student access to calculator and computer technology.

Finally, perhaps the strongest conclusion that I drew from the experience of this ILP is that "real" math education does indeed possess the power to inform, motivate and energize students in new ways. Just as much as "disconnected" mathematics tends to discourage or bore students, competently "connected" and humanely contextualized math tends to encourage and excite students. More to the point, math *educators* can have significant and positive influence on students almost in direct proportion to their own enthusiasm and passion for the beauty and authentic insights of the mathematics they teach. Many of the authors I encountered in my scholarly and non-scholarly research attested to this positive impact potential (see, for example, Boaler, 2006; Gutstein, 2007; Stocker, 2008), and I believe that I was fortunate enough to personally witness some of that potential being realized when I piloted a few of the components of the modular resource package with a group of first-year university students. Learners of any age and in any subject area, I suppose, bring to bear their full intellectual and emotional energies whenever they are engaged with ideas and topics that touch their own concerns and/or the concerns of people with whom they readily identify. When it matters, it matters, and mathematics is no exception.

As already noted, I enjoyed the opportunity to pilot some of the elements of "Mathematics for a Broken, Beautiful World" in a first-year university mathematics classroom as I was developing the modules. This opportunity came in the context of my work as a mathematics instructor for the Mi'kmaq-Maliseet Institute (MMI) of the University of New Brunswick in Fredericton, New Brunswick, Canada. In particular, I implemented the role-play

activities from the module concerning compound interest and debt in a course of finite mathematics, and I introduced various components from the rates of change and population growth module in the context of a calculus course. In both courses, the class group size was ideal (around fifteen students) for extensive interaction with students as well as for garnering feedback regarding the strengths and weaknesses of the modular activities. I expect to continue in my employment at MMI with both of the courses, so I plan to have more opportunity to use the modular resource package in the near future. In addition, I may have the chance to extend my employment to the growing Fredericton campus of the New Brunswick Community College and/or to another Fredericton-based university, and so to introduce applicable elements from the modules in courses through those institutions.

In all, the experience of this ILP leaves me feeling more informed, equipped, student-sensitive, and inspired as a mathematics educator. I look forward to moving into the future with the modular resource package. Not only do I anticipate having continued and further opportunities to implement the project in my own teaching, but I also intend to formally offer parts or all of "Mathematics for a Broken, Beautiful World" to math teachers as well as math teacher educators, both locally (here in New Brunswick) and more widely in Canada and the United States. I hope to present the resource package and some of my insights from developing it at "Creating Balance in an Unjust World," a North American conference for social justice mathematics. And most of all, I am eager to enhance the existing modules and add to their number on an ongoing basis. I have already collected—and provided in the modular resource package itself—some ideas for potential additional modules (with the key mathematical concept for each in italics):

- an *ethnomathematical* unit concerning, for example, the occurrence and meaning of fractal geometric design in indigenous African communities

- further investigation of *rates of change* through an examination of widespread species extinction or the decline in human linguistic diversity
- a *statistical analysis* of polling and/or voting systems
- an investigation into various *mathematical models* of climate change
- an exploration of *linear programming* techniques through the context of chocolate and/or coffee production and fair trade policies
- a consideration of the law of diffusion of innovation and its *statistically normal* (bell curve) properties
- a module concerning the use of *probability* in public health strategies—for instance, in the context of screening for diseases like AIDS or cancer
- a project on the eight United Nations Millennium Development Goals (MDGs) for 2015 and the *numerical benchmarks* they strive to establish

So the journey of "Mathematics for a Broken, Beautiful World" is underway, and I hope for it to be a small but effective contribution to the exciting, important, and growing movement of humane mathematics education.

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