AC 2010-1790: INTEGRATING SOCIAL JUSTICE IDEAS INTO A NUMERICAL METHODS COURSE IN BIOENGINEERING

George Catalano, State University of New York, Binghamton

Caroline Baillie, Western Australia

Donna Riley, Smith College

Dean Nieusma, Rensselaer Polytechnic Institute

Chris Byrne, Cascadia Community College

Margaret Bailey, Rochester Institute of Technology

Katy Haralampides, University of New Brunswick

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Abstract

A newly developed course introduces students to the analytical and numerical techniques that will be utilized in subsequent bioengineering courses to analyze the behavior of complex systems. The illustrative case studies in the form of course modules employed in this course have as a focus various issues related to questions of social justice and include wealth distribution, developing a social justice index, exploring the costs of health care in the United States and examining poverty trends in the United States and around the world.

Introduction

The main educational objective of the bioengineering department at Binghamton University is to provide students with an understanding of living systems as complex systems, and to develop in the student both the understanding of, and confidence in working with, complex systems, whether biologic, or biomimetic. From the department's perspective, the ability to exploit new opportunities and solve problems within the domain of complex systems will be the hallmark of successful engineers in the 21st century. Towards this goal and throughout the program, there is an explicit emphasis on the use of *Mathematica* in the solution of problems involving iteration, differentiation, integration, solution to ODE and PE, matrix manipulation, and vector algebra.

The present course aims to develop numerical and modeling skills through a consideration of issues related to social justice. The particular issues which have been integrated into this required sophomore level course include distribution of wealth, the costs and tradeoff associated with health care, the development of a social justice index (SJI) analogous to an environmental quality index and recent poverty levels and trends in the United States and around the world.

The question of social justice is placed in the broader context of sustainability. At the outset of the course, guided discussions were accomplished with the focus being to introduce students to the concepts of sustainability and sustainable development. Since the 1980s sustainability has been used more in the sense of human sustainability on planet Earth and this has resulted in the most widely quoted definition of sustainability and sustainable development, that of the Brundtland Commission[1] of the United Nations:

> "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Continuing, "sustainable development is a pattern of resource use that aims to meet human needs

while preserving the environment so that these needs can be met not only in the present, but also for future generations."

The Bruntland Commission, its characterization of sustainability and sustainable development, are used as entry into discussions related to the notion of social justice. Carful attention is paid to developing and maintaining a safe environment where students are free to challenge any/all assumptions or perceived biases in the formulation of the problems, which are considered in the course. There is no effort to indoctrinate any particular political view. In fact students are routinely and anonymously questioned about the 'objective' nature of the course material throughout the term. The responses point to the realization among the students that they are analyzing or modeling complex systems in a similar way as they are challenged and will be challenged in other bioengineering courses. The particular set of problems employed in this class happens to focus on issues related to social justice.

The course is taught in a structured studio format. During the first four weeks of the semester, students are led through the *Mathematica* tutorial notebooks used by Packel and Wagon in their annual workshop *Rocky Mountain Mathematica*. [2] After finishing the different (eight) tutorials, each of the four course modules is introduced. Two weeks of in-class time is devoted to each module. Students are arranged in teams of three or four per group with the group assignments alternating between self-selected, random or purposefully chosen. The first period of each two-week block is used to introduce the topic, discuss any new analytical or numerical techniques that are relevant and, lastly, talk briefly about the broader societal issue(s) that each module brings forth. The remaining two class periods then are used by the students to work on finishing the module. It should be pointed out that though students are put into groups and encouraged to talk about the various parts of the problems, each student is ultimately responsible for submitting his/her own work.

Additionally as part of the grading structure in place for this course, students have weekly homework assignments, an out-of-class final exam and an in-class final exam. These requirements add up to 60% of the total final score.

Integration of Issues using Course Modules

Students were assigned four course modules after the introductory portion of the course. Each module accounted for 10% of the final grade and in addition each had both a technical part and a reflective essay part. Brief descriptions of each of the various modules used in the first two offerings of the course follow.

- Course Module 1: Gini Coefficient and the Distribution of Wealth.

The Gini coefficient is a measure of inequality of a distribution.[3] It is defined as a ratio with values between 0 and 1: the numerator is the area between the Lorenz curve of the distribution and the uniform (perfect) distribution line; the denominator is the area under the uniform distribution line. The Gini index is the Gini coefficient expressed as a percentage, and is equal to the Gini coefficient multiplied by 100. The Gini coefficient is often used to measure income inequality.[4] Here, 0 corresponds to perfect income equality (i.e. everyone has the same income) and 1 corresponds to perfect income inequality (i.e. one person has all the income, while everyone else has zero income).

Students must use *Mathematica* and for the data set provided, develop a plot with population as the x-axis variable and wealth as the y-axis variable. They then calculate the coefficient and through research using the internet, find the value of the most recent Gini coefficient for the U.S. as well as at least 10 additional countries insuring several of the countries are in the West, several in the East and several in South America. After completing the technical part of the module, students are asked to consider if the existence of poverty in the U.S. getting better or is it becoming worse. They are asked to reflect upon their findings and to consider what if any ethical responsibilities do they have both for citizens of the United States as well as other people throughout the world.

- Course Module 2: Developing a Social Justice Index (SJI)

Consider the issue of poverty in the world today. What are our responsibilities -if any towards - the underdeveloped world and/or those impoverished? If engineering has only lately addressed responsibilities that we have as a profession towards the health of the Earth, even less attention has been paid to the question of our professional responsibilities towards the poor. Somehow until very recently that notion has been seen to be outside our ethical responsibilities. Today however there is a growing belief that engineering does have such a responsibility. The National Society of Professional Engineers is currently debating whether or not to include similar language in its Code of Ethics.[5]

Consider the following effort to quantify the health of the planet.[6] The European Union has recently been developed a method termed the Environmental Quality Index. (QOL)
An environmental quality index that takes into consideration all aspects of the natural environment of a consumer's life could be taken to be equal to the mean of these variables. However, a mean cannot be computed directly, because of differences in the units of measurement of the above variables. Therefore, these variables need to be scaled before a mean is computed. This QOL only addressed issues related to the health of the environment. It does not address issues of social justice and poverty. An actual index for social justice and poverty does not exist. That is the challenge given to students. The requirements are that they include at least ten (10) factors and the factors must be quantifiable. Students can develop a SJI for

one state, a region of the country or the entire U.S. Once developed, students are asked to model the SJI as a function of time, estimate anticipated values of the SJI in ten years. Once again, *Mathematica* was required for the completion of the assignment. After completion of the index, students are asked to reflect upon the following set of questions:

- What are your reflections on issues you identified for the SJI model? Were you surprised by any of the data? Disappointed?
- What do you see as your responsibilities relative to questions of poverty and social justice as an engineer? A leader? A citizen?

- Course Module 3 Costs of Health Care

In the United States, the costs associated with a person's health care are primarily a responsibility of that individual and, as a result, individuals with more wealth can afford better medical care. A source code using *Mathematica* that allows students to actually carry out calculations related to this issue also is presented. The code is part of the Wolfram Demonstration Project[7] collection of computer codes.

An individual's happiness (or "utility") often depends on their wealth and their health. Spending on medical services, however, can often improve one's health. This Demonstration explores tradeoffs between wealth and health permitted by medical technology. The cost of medical services to improve health from some baseline by an amount is modeled by the solution to a differential equation. The Demonstration provides a graphic showing the different utility contours, with a black locus showing the possible wealth-health states permitted by medical technology and a red point showing the optimal level of wealth and health given as a baseline position and the cost of medical services.

In this module, students explore the issue of health acre and costs and ask the following set of questions:

- Is there a point where continued rising expenditures on medical treatments and technologies do not result in significant improvement in our health care?
- Is there a trade-off point?
- Would it be a more efficient use of resources if we had a limit on such expenditures?

- Course Module 4 Poverty Levels and Trends in the Unites States

There is growing conversation both within the U.S. and throughout the global community concerning the growing disparity between the haves and have-nots segments of the global community. Some argue that such a trend leads to a more unstable world. Others state that we have a moral obligation to help the underdeveloped world or the poor. Still others maintain that the existence of poverty lies outside the responsibility of engineers and engineering. The present case study will challenge you to explore your values and beliefs as well as use your analytical skills.

Students are challenged to develop a set of predictive models based on available data. The predictive models must include at a minimum: numbers in poverty and poverty rates; poverty rates by age; distribution of income in the United States; and predictions for calendar years 2010, 2015, and 2025. Having predicted the trends and values for the various parameters detailing poverty in the U.S. over the next several decades, students are asked to reflect upon their meaning as future professionals, as well as members of the U.S. society. In addition the following set of questions are posed:

- Are you surprised by the numbers or the trends?
- Does engineering have anything to offer?
- Should engineering be concerned with the existence of poverty? How so?
- Should engineering education be concerned? How so?

Student Feedback

Binghamton University uses a standard student evaluation mechanism. A summary of the results is provided in Table 1.

1. My interest in subject before course	52	6	11.5 %	Low
		38	73.1 %	Medium
		8	15.4 %	High
2. My interest in subject after course	52	6	11.5 %	Low
		26	50.0 %	Medium
		20	38.5 %	High
3. Difficulty (relative to other courses)	52	2	3.8 %	Low
		46	88.5 %	Medium
		4	7.7 %	High
4. Workload (relative to other courses)	52	2	3.8 %	Low
		38	73.1 %	Medium
		12	23.1 %	High
5. Usefulness of texts	52	44	84.6 %	Low
		8	15.4 %	Medium
		0	0.0 %	High
		0	0.0 %	Not Applicable
6. Usefulness of course modules	52	26	0.0 %	Low
		0	38.5 %	Medium
		26	61.5 %	High
		0	80.8 %	Not Applicable
7. Usefulness of examinations	52	0	0.0 %	Low
		4	7.7 %	Medium
		28	11.5 %	High
		24	46.2 %	Not Applicable

Table 1: Student Feedback for First Two Offerings

The responses from students to the course module approached described are extremely varied. Various tools have been used to assess student responses including group discussion, open-ended in-class essays and formally computer-scored student evaluations. Two trends observed after first two offerings of the course are the following: students respond (both negatively and positively) more strongly to the course modules then any other part of the course; and a statistically significant higher percentage of female then male students respond favorably. We plan on gathering additional longitudinal data detailing the progress of the different cohorts of students as they progress through their undergraduate programs.

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