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Special Issue on Public Policy: Front Matter

Engaging the World: Differential Equations Can Influence Public Policies

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The CODEE Journal is a peer-reviewed, open-access publication, distributed by the CODEE (Community of Ordinary Differential Equations Educators) and published by the Claremont Colleges Library, for original materials that promote the teaching and learning of ordinary differential equations.

<u>Foreword</u>

It is with great pleasure and honor that we introduce the Third Special Issue of the CODEE Journal with the theme, ***Engaging the World: Differential Equations Can Influence Public Policies.*** Here, we share different ways of making connections between mathematical modeling via differential equations and the practical realms of public policies. As educators, researchers, and enthusiasts of mathematics, we recognize the profound impact that differential equations play in shaping our understanding of complex systems and in turn, informing sound public policy decisions.

The articles within this special issue span a spectrum of perspectives, from innovative teaching and course administration ideas to insightful investigations into the practical applications of differential equations to many real world applications such as epidemics, population dynamics, oligarchy and taxation, mandatory voting, groundwater flow, aircraft takeoff distance, and sustainability projects. Indeed, this special issue is a testament to the interconnectedness of classroom and research mathematics to societal well-being.

We extend our sincerest gratitude to all our contributors and reviewers for their dedication in making this Third Special Issue a reality. They are all seasoned mathematics educators and emerging mathematics scholars from the USA, Lebanon, and Australia. May the insights that they share in this Special Issue inspire continued collaboration, dialogue, exploration, and innovation in the teaching and learning of differential equations.

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Dedication

Bev West
CODEE Journal Editor

I first met Bev Henderson West at the Joint Math Meetings in 1998 that were held in Baltimore when I participated in the MAA minicourse on "Interactive multimedia modeling and differential equation solving" that was organized by Michael Moody, Robert Borrelli, Courtney Coleman, and Beverly West. That was my introduction to ODE Architect. This was cutting-edge technology and pedagogy. While I had already fallen in love with differential equations, the introduction of technology opened new opportunities for me to convince others of the breadth, depth, and beauty of differential equations.

I remember Bev talking about the attention to detail that went into designing and implementing the different modules available within ODE Architect. Attention was spent on both the visualization and on the numerical accuracy. Today, the graphics and simulations in ODE Architect show their age, but clearly, this was a watershed moment in the evolution of the teaching of differential equations.

I was immediately welcomed into CODEE, and immediately felt that I was an accepted member of the "community", even though it would be many years before the Consortium of ODE Educators officially became the Community of ODE Educators. As I look back on my career, I see now that this was when I saw opportunities to commit my scholarly energy towards educational issues. I have now been involved with CODEE for more than 25 years.

Almost every one of my interactions with CODEE has included Bev. Others may have had more dynamic personas, but Bev was always there organizing, scheduling, communicating, and greeting old friends and making every person who showed up to a talk by a CODEE member feel welcomed. While her love for differential equations was always clearly visible, she was not pushy. I felt she was genuinely happy to see me, and understood that I was not always able to participate in everything associated with CODEE.

For any community to survive, it needs new members. Some of these new members need to be willing to take on organizational and leadership positions. Finding one person to fill Bev's shoes is a real challenge. I think the best solution is to build a team within the community that, together, can oversee CODEE's needs for the years to come.

As I was going back through my archives and memories to remember some of my own history with CODEE I came across an article Bev wrote for the CODEE article in 2016, *Teaching Differential Equations without Computer Graphics is a Crime*, (CODEE Journal, v11, article 2 https://scholarship.claremont.edu/codee/vol11/iss1/2). Here is the abstract of that paper:

In the early 1980s computer graphics revolutionized the teaching of ordinary differential equations (ODEs). Yet the movement to teach and learn the qualitative methods that interactive graphics affords seems to have lost momentum. There still exist college courses, even at big universities, being taught without the immense power that computer graphics has brought to differential equations. The vast majority of ODEs that arise in mathematical models are nonlinear, and linearization only approximates solutions sufficiently near an equilibrium. Introductory courses need to include nonlinear DEs. Graphs of phase plane trajectories and time series solutions allow one to see and analyze the crucial behaviors, whether or not analytic solutions exist. Furthermore, interactivity is key to experimenting with parameters in order to modify behaviors. Now, a quarter of a century later, we have far more technology--but many features of the original software have been lost in the rush to the future. We have both educational and software concerns. This is not only an academic issue--scientists at multiple nonacademic agencies (e.g., FDA, NIH, USCGS) immediately took up our software tools in the late 1980s, and increasingly more of our students come from fields that did not traditionally require mathematics background. We should not be depriving today's students of the skills to analyze behaviors of solutions to ODEs.

The situation today is not better. Technology might be more advanced, more widespread, and more available, but how many of our colleagues still teach without using graphical tools for seeing solutions of differential equations? What can CODEE do to continue to advocate for the modernization of the teaching of differential equations that Bev (and many others) have been working on for the last 35 years?

While I do not have explicit answers for these questions, I do know that I am thankful I attended that MAA mini-course in January 1998, met Bev, and became a part of CODEE. Thank you for all that you have done for me and others individually, and collectively, and for your enduring passion for the teaching of differential equations. I know I am looking forward to the next time we get to meet, and to welcoming even more people into the Community of ODE Educators.

Thank you, Bev.

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<u>Preface</u>

Public policy is an important issue because it provides structures and strategies by which our society can work to address and resolve some of the current social, economic, environmental, public health, educational, behavioural, and other issues. Mathematical modeling of real-life problems through differential equations can help in understanding how systems in our society operate and can provide guidance in problem-solving and analysing the effectiveness of public policies that govern society's response to issues. While a one-semester class can be too short to have actual influence on public policy, there is much opportunity to widen students' perspective and prepare them to do the necessary research and guide them in how to write and present their results effectively.

Following two CODEE special issues on engaging the world (*Differential Equations in Today's World*, and *Linking Differential Equations to Social Justice and Environmental Concerns*), we have sought in the current issue contributions that highlight how DEs may be used to reflect on questions such *as how to describe public policies quantitatively and embed these descriptions into differential equations*; *how to measure the effectiveness or adjust public policies to fit a desired purpose*; and *how we can develop mathematical fluency among students when discussing mathematics and public policy*. The collection of papers received and published speak to the diversity of where and how differential equations can influence public policies in governmental and non-governmental agencies. Due to the variety of topics covered, we have grouped the papers into four categories.

<u>Category I</u> focuses on epidemics; naturally, the COVID pandemic constitutes the majority of papers. *C. J. Edholm, N. L. Falicov, L. N. Wartman, M. A. Hohn, E. Y. Lee,* and *A. E. Radunskya* discuss a real time project to help college administrators decide whether to reopen their campuses in Fall 2021, where a key element was the introduction of vaccines. To help guide this decision, authors formulated an ODE model capturing the dynamics of the spread of COVID-19 on a residential campus. They then created an App which could be operated by the policy-makers themselves to explore other parameter settings. This unique contribution allowed the administrators to have a deeper understanding of the models *and* the opportunity to try their own input. Findings were extrapolated to a general audience, thus democratizing the policy-making process.

The paper by *C. Goosen*, *M. I. Nelson*, and *M. Watanabe* describes a classroom project for a modelling scenario using the SIR epidemic model, in a simulated community of 3000 people. A theoretical mayor had asked students of a third-year mathematics course to determine what would happen, before vaccines were introduced, to the population if no action is taken. Then they were asked to evaluate policy options: lockdowns, social distancing, hand hygiene, masks, (in various combinations) and to recommend the best course of action. The students made oral presentations to their classmates, who played the roles of mayor and community members.

D. C. Griffin and *A. Mangum* discuss how SIR models have generally failed to capture the nature of the COVID-19 pandemic's multiple waves, primarily because they do not take into account public policies such as social distancing, mask mandates, and the "Stay-at-Home" orders. The paper examines experimental data from Spartanburg County, South Carolina, giving insight into the changing social response toward the pandemic within the county.

Category II is on engaging students in the classroom. *B. Luo* presents a detailed approach to planning and teaching an intensive five-week summer Differential Equation course. The paper suggests tips for creating an interactive and supportive learning environment to optimize student engagement, with a focus on real world situations and a special attention to ways differential equations can be relevant to creating public policies.

M. Ghrist writes about environmentally focused writing assignments developed and implemented in an integral calculus and differential equations courses. Two assignments, one on carbon storage and the other on pollution in the Spokane River, focus student attention on sustainability concerns while also developing other essential skills such as technical writing and environmental awareness.

Category III is a collection of three papers on population dynamics. *J. Sandefur* examines differential equations that model the sustainable harvesting of species having different characteristics. The focus is on how maximizing profit can affect the harvesting strategy. When this leads to collapse of a particular species population, regulation becomes necessary to restore the stock.

Back to the classroom, *L. Zhang*'s paper is about an undergraduate mathematical modeling course where predator-prey models are taught to students who are expected to use the numerical and graphical methods to observe the qualitative long-term behavior of whale and krill populations. The author emphasizes the importance of strengthening students' awareness of protecting endangered species and its impact on climate change and global habitability.

Mountain pine beetles cause a significant destruction of Colorado lodgepole pine forests. The projected warmer environment increases the problem, emphasizing the need for effective land management policies. In the paper by *S. A. Strong* and *M. Maes-Johnson*, (partial) differential equations are used to model this insect-plant interaction, offering insights into possible mitigation strategies.

Category IV is an assortment of unique modelling projects using differential equations.

C. E. Cavagnaro, an airplane pilot and instructor, showcases in her paper an application modeling aircraft motion to ensure safety during takeoff. Aircraft safety is a matter of public concern, although it is the FAA (Federal Aviation Administration) that makes the regulations. In trying to understand the takeoff rules, the author raises some circumstances for which the current rules fall short of their goal.

B. Boghosian and C. Börgers explain how modelling can be used to explore the effects of taxation on the emergence of oligarchs. The model discussed suggests that oligarchs will emerge when wealth taxation is below a certain threshold, and that taxation of income and capital gains alone cannot prevent the emergence of oligarchs.

The paper by *C. Börgers*, *N. Dragovic*, *A. Haensch*, A*. Kirshtein*, and *L. Orr* presents mathematics relevant to the question whether voting should be mandatory. It models how politicians might adjust their positions to raise their share of the vote. Various scenarios are explored using an app that the authors have developed engaging students in an a rather unusual context.

V. Donnay describes in his paper how to introduce in an introductory modeling course the topic of solar power, how to apply Euler's method for differential equations to determine the energy generated, and how to provide a variety of lesson extensions that engage students in an exploration of policy issues related to climate change. These examples are used to empower learners to use their mathematical skills to help create solutions. The unique outcome of Donnay's classes is that he develops community partners who work with the students, so these projects actually *do* bring about visible public policy results!

M. A. Karls and *C. Evrard* describe a tabletop physical model that illustrates how groundwater water flows through an aquifer, how water wells work, and the effects of contaminants introduced into an aquifer. The authors explain how the model can be used to simulate groundwater flow through an aquifer with a no flow boundary condition. This has obvious implications for influencing public policy on water quality.

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There was one more paper that did not get finished for the special issue, because the lead author, Adhvaith Sridhar, became very ill. We hope he will be able to submit it later for the Regular Issue of the CODEE Journal

A. Sridhar, *P. Xu*, *S. Jang*, *C. Jones*, and *K. McLaughlin* study the effect of an outbreak of the H5N1 variant of the bird flu on human health and economic growth. In this student paper, a novel SIR model is used to predict the spread dynamics in avian populations. Sensitivity analyses are used to determine the most effective control and preventative measures. Authors describe the applications of the model to the enactment of policy surrounding a response to a theoretical outbreak of the avian influenza in human populations and provide healthcare providers and public health departments with a tool that can quantitatively combat disparities in future public health scenarios.

The significance of this paper for us is that the authors were all students when they did this research. It is an example of the lovely work that student researchers can do, and we want to make it clear that the CODEE Journal welcomes such papers.

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