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Co-Adventurers in Discovery: Collaborative Research Between Undergraduate Students and Faculty

Rajeswari Murugan
Nova Southeastern University

Evan Haskell
Nova Southeastern University, haskell@nova.edu

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About the Authors

Rajeswari Murugan is a biology major at the college with minors in mathematics and chemistry. She is dually admitted into NSU's College of Osteopathic Medicine and is part of the Undergraduate Honors Program. Murugan also serves as a member of The President's 64 elite organization at NSU. Her additional leadership roles at the university include head lab assistant for General Chemistry courses, peer leader for the college's Academic Society Program, vice president of Rotaract, and former secretary and pledge class president of Alpha Phi Omega. She is also an active member of the Pre-Medical Society, Clinic Exploration Program, and the Emerging Leaders Certificate Program. Murugan's research experiences include mathematical modeling of cardiac arrhythmogenesis and cytotoxicity studies on prostate cancer cells at the Rumbaugh–Goodwin Institute for Cancer Research.

Evan Haskell, Ph.D., associate professor at the college, is an applied mathematician who earned his Ph.D. from the Courant Institute of Mathematical Sciences at New York University. Prior to arriving at NSU, Haskell was a member of the cognitive neuroscience sector of the International School for Advanced Study in Trieste, Italy, and the mathematics departments at University of Utah and College of William and Mary. Haskell has published numerous scholarly articles on developing and analyzing models of large-scale neuronal networks.

Co-Adventurers in Discovery: Collaborative Research Between Undergraduate Students and Faculty

by Rajeswari Murugan and Evan Haskell

There are many opportunities available beyond the classroom for undergraduate students to engage in cutting-edge scholarship. Some of the opportunities include study abroad, internships, and independent study. We strongly suggest that students experience such programs. Independent study courses can serve not only to sharpen the student's engagement skills with the open-ended questions of current research, but also to enhance his or her own relationship with faculty. In this article we share the experiences of a biology student and a mathematics faculty member coming together as co-adventurers learning from each other about the mechanisms and mathematics involved in cardiac arrhythmia through collaborative mathematical modeling research. Biology and mathematics have a long history of an explosive synergy that enriches and extends both fields (Cohen, 2004) (Reed, 2004), and this synergy led us to the fruitful journey reported here. As there is no end in sight for opportunities to engage in such multi-disciplinary student-faculty collaborative research, we encourage everyone to take advantage of such opportunities.

The Student Perspective

Dr. Haskell invited me to participate in a research project through an Independent Study in Mathematics course. This course would not only widen my knowledge of models in mathematics, but would also combine my two passions for mathematics and cardiology together. Another advantage of this course is that it can count towards an intended minor or major in mathematics. Thus, the opportunity to complete the final credits towards my mathematics minor and my passion towards the subject itself attracted me to the project. The research experience began with the submission of a project proposal form with an essay in which I defined the problem that I would like to explore. Dr. Haskell had suggested combining my interests in cardiology and mathematics by working with a mathematical model that models the electrophysiology of the heart. After an organizational meeting to discuss research methods and my maintenance of a research journal to record the summary of articles read, new vocabulary, and questions for focus in the research project, we agreed to regular meetings. In weekly meetings with Dr. Haskell, we discussed the literature we had read and the mathematical research that would be explored. With each meeting, my knowledge of mathematical modeling and its correlation with the heart widened. After a few months of researching the mathematics and related cardiology literature, I made progress towards developing the research project results. The initial suggestion and subsequent discussions led to us investigating an unexplored issue of how sex differences in cellular anatomy can lead to physiological differences in the potential occurrence of ventricular fibrillation.

Mathematical modeling comprises three major steps beginning with scientific observation of the phenomenon to be modeled followed by a quantification of the dynamics of the observed interactions that lead to the phenomena. Ultimately, computations and model analysis are performed to make predictions about the mechanisms involved in the genesis of the phenomena that may not be experimentally accessible either because of the amount of data that would be required to be collected, or technological or ethical limitations. After picking the suitable mathematical modeling technique for my interest, we continued to explore the model across various literatures. I really learned the importance of researching for journal articles that include the studies already done on the project. These articles will not only help explain the model components and development process, but also guide me to find suitable parameters for the model. I changed some parts of the model to include variables that helped narrow the research and to qualify for the American Association of University Women (AAUW) award for the advancement of issues of concern to women at the Nova Southeastern University (NSU) Undergraduate Student Symposium.

Once the symposium was near, we found computational tools for the visualization of the two and three spatial dimension versions of the model. Using the screen shots of our simulation results, we completed the poster. My writing capabilities also improved drastically while writing for the poster presentation. During the symposium, I not only gained presenting skills, but also learned how to answer difficult questions from those interested in the results of the research project. After the presentation at the Undergraduate Student Symposium, the presentation won the AAUW Award. Not many expected a mathematical modeling poster at the symposium to win such an award.

After the symposium, the rest of the semester was focused on presenting the project as part of a Mathematics Colloquium Series talk. The presentation was a great opportunity to not only present the results, but also for me to help gain more public speaking experience. It was a great experience overall because the mathematics faculty began to ask questions and also gave suggestions about the research that I would not have thought of otherwise. Research in mathematics is truly a community effort!

So, what did I learn from mathematical modeling? Mathematical modeling can represent real-world phenomenon and typically serve to predict the future or outcome of the phenomenon. We analyzed different models related to the electrical control of the heart. The model for the electrophysiology of the heart and mechanisms leading to fibrillation resulted in a system of reaction diffusion equations describing how the propagation of electrical activity through the cardiac tissue induces the muscular activity of the heart, which in turn causes the flow of the transportation system throughout the body. The relation between these reaction diffusion models of the electrochemical control of the heart and the real-life phenomena of arrhythmias and the destabilization of the model representing defibrillation was analyzed. Defibrillation appears in these models through pattern formation mechanisms to exhibit a spiral wave of electrical activity through the heart resulting from symmetry breaking of the normal traveling wave of electrical activity through the heart.

I am very glad Dr. Haskell approached me to further my interest in mathematics during my first semester at NSU. This led to my pursuing a mathematics minor to augment my study of biology. In conclusion, I strongly recommend that students should maintain a great relationship with a professor that they can get along with. Not only will this help them gain a professional faculty member with whom to discuss academics, but also a source for a letter of recommendation, a potential research partner, and possibly a source for a job as a lab assistant. Additionally, this faculty member may even serve as a great mentor long after the last class with them is over.

The Faculty Perspective

One of the privileges of teaching undergraduate courses is getting to spend classroom time with many bright, motivated students with a very diverse set of interests. As an applied mathematician focusing on mathematical modeling, I have received specialized training for identifying and encouraging an interest in mathematics. I find a powerful way to nurture a student’s yawp comes in bringing together mathematics and their non-mathematical interests. A mathematical yawp is defined by Su as “that expression of surprise or delight at discovering the beauty of a mathematical idea or argument” (Su, 2010). Part of the beauty of mathematics is its deep connections with the natural world and our ability to use mathematics to help us understand and make predictions about the natural world.

For undergraduate students with a good training in freshman and sophomore mathematics, mathematical biology can be an extremely appealing subject that is well suited for undergraduate research projects as biology is very diverse and relatively little modeling has been done in many areas of biology (Reed, 2004). The primary questions of biology concerning structures, mechanisms, pathologies, repairs, origins, and functions/purposes combined with the various levels of organization provide many opportunities for mathematical modeling and challenges for new mathematics arising from biology’s heterogeneity and interactions across multiple scales in time and space (Cohen, 2004). When engaging in this area of scholarship, one must be careful not to look for a mathematics of biology as the problems of biology are too diverse to be derived from a few simple principles in the same way Newton's law of motion provides a conceptual framework for classical mechanics (Reed, 2004). Nonetheless, I find it quite impressive how many biological systems appear to continually conduct complex mathematical operations.

After learning about mathematical modeling and its predictive powers in an Ordinary Differential Equations course, Rajeswari Murugan came to speak with me about combining her interests in cardiology and mathematics. The heart and mathematics have a long history in mathematical biology. Observations and quantitative measurements of the heart by William Harvey in the early 17th Century is a pivotal event in the foundations of the modern interaction between biology and mathematics. Through his careful observations and measurements, Harvey was able to make mathematical calculations that predicted the existence of capillaries more than half a century before they were first observed under a microscope by Marcello Malpighi, setting a very high standard for the application of mathematics in biology (Cohen, 2004). With a rich history of mathematical modeling and the heart, Ms. Murugan and I began our co-adventure in discovery.

Together Ms. Murugan and I studied mechanisms for the formation and break-up of the spiral wave of electrical activity characterized by cardiac arrhythmias. In this project we formed a multi-disciplinary collaboration that allowed us to truly engage in the spirit of being co-adventurers in our discovery. Ms. Murugan served as a local expert in all things cardiac, teaching me about the structures, mechanisms, pathologies, repairs, origins, and functions of the heart. With this information we explored the mathematics necessary to describe these processes and computational tools to visualize the mathematical model. As a result of this co-adventurer process, we learned about reported differences in the anatomy of cardiac cells for males and females and were able to explore the physiological implications for the genesis of ventricular fibrillation by expanding our model. Through this co-adventurer process we were able to expand our mathematical modeling project to one that served the mission of the AAUW for advancing equity for women by exploring a mechanism that may make women at greater risk for ventricular fibrillation, suggesting an area of focus for women's health.

The Co-Adventurer Outcome

So, what did we learn from our co-adventure in a collaborative research project? Firstly, we learned that research involves a community with very diverse backgrounds and approaches. From this community we learned new ideas such as the potential for sex differences in cellular anatomy to have profound physiological implications. We also developed greater appreciation and awe for the synergies of biology and mathematical modeling and computation. As we learned more about the mechanisms involved in cardiac arrhythmias, our creativity and critical thinking skills were constantly challenged to uncover the interactions of these mechanisms. Moreover, we enhanced our communication skills as we interacted with the community in various formats from a poster presentation to a colloquium talk to general discussion. Perhaps, most importantly, the research project opened a window of opportunity to create a long lasting faculty-student relationship.

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