Interdisciplinary education

Professors Hristo Kojouharov and James Grover describe the motivation behind their latest teaching programme which integrates biology and mathematics, thus enabling undergraduates to take an interdisciplinary approach to their research projects.

Firstly, could you explain the inspiration behind your latest project – Undergraduate Training in Theoretical Ecology Research (UTTER)?

Problems arising in science today are complex and often best addressed by teams of researchers from several disciplines. In particular, progress in the biosciences increasingly depends on the integration of mathematics. It has historically been difficult for mathematics to play a strong role in advancing biological knowledge. Students in the two disciplines traditionally have very different training, and there are shortages of mathematicians familiar with biology, and of biologists with quantitative training. As a result it has been hard to initiate collaborations between biologists and mathematicians.

Therefore, integrating biology and mathematics should be a focus of training students. The central theme of the UTTER programme's research direction is mathematical ecology and epidemiology. The programme articulates well with UT Arlington's institutional goals of enhancing interdisciplinary research and education.

What motivated collaboration between the Departments of Mathematics and Biology at the University of Texas at Arlington and what have been the benefits?

The Mathematics Department has long had an Applied Mathematics group that has included faculty interested in Mathematical Biology, while the Biology Department administers a doctoral programme in Quantitative Biology. The two of us have been collaborating for over 10 years, and had a prior interdisciplinary National Science Foundation (NSF) research grant before applying for funds for the UTTER programme. When the NSF began funding undergraduate training programmes, it was natural for us to collaborate in establishing such a programme and to recruit several other faculty participants from both departments.

How do you position yourself within the UTTER project? What are your principal responsibilities?

HK: I am the Director of the UTTER programme, in charge of project management and coordinating student recruitment and selection. In addition to mentoring UTTER scholars and directing their research projects, I co-teach with Dr Grover the new interdisciplinary UTTER courses and the five-week intensive summer research workshop.

JG: I serve as Co-Director of the programme. I am the primary instructor for one of the new courses we developed, teaching about two-thirds of the material while Dr Kojouharov does the remainder. In the second course we reverse these roles. The material I teach focuses on formulation and biological interpretation of mathematical models, to help students translate their knowledge of biological processes into mathematical representations and understand how model predictions lead to biological insights. Dr Kojouharov focuses on mathematical and numerical analysis of the models.

How will this type of partnership benefit other disciplines at UT Arlington?

Many current scientific challenges arise at the interface of different disciplines, and often they involve quantitative aspects for which mathematics is needed. Our programme illustrates the value of having students and faculty in mathematics and other disciplines work closely together in the classroom and on research projects. We hope that our programme serves as a model and an inspiration to others. A natural avenue for extended collaboration is through bioengineering, and already one of the graduate students who served as a student mentor in the UTTER programme has completed a dissertation that involved mathematical modelling and the bioengineering of tissue implants.

Could you discuss your plans for the future of this project?

The programme at NSF that funded the UTTER programme will not continue, so we must transition to self-supporting status. The scholarships and large, team-based collaborative research projects supported by our funding are not likely to continue, but other aspects of the programme have the potential to endure. The courses we developed form the core of the new Mathematical Biology option in the Mathematics Bachelor’s degree programme, and the research focus of these courses will continue to inspire undergraduate students to pursue opportunities for research with individual faculty members. Now that we have cultivated a core of mathematicians and biologists who collaborate on interdisciplinary work, we are hoping to expand from undergraduate to graduate training.

Are there any other related activities that you are involved in outside of the UTTER programme?

Faculty affiliated with the UTTER programme are very active in other aspects of education and public outreach. Dr Kojouharov is the Founding Chair and Organiser of the UT Arlington Calculus Bowl, an annual event attracting over 200 outstanding Mathematics students and their teachers from over 20 high schools across the North Texas area. Dr Grover is active in the interdisciplinary graduate programme in Earth and Environmental Sciences, for which he organised a mentoring programme that involves experienced professionals from the Dallas-Fort Worth region.
THE UNDERGRADUATE TRAINING in Theoretical Ecology Research (UTTER) programme at the University of Texas at Arlington is a pioneering undergraduate course which is offering an integrated research and education experience for undergraduates in both biology and mathematics, combining these disciplines in a course which is aimed at the needs of cutting-edge research in the 21st Century. Five cohorts of eight students each pursue a two-year programme of mentoring, seminars, interdisciplinary research, and specially designed coursework in mathematical biology. Each component and new course is jointly developed and coordinated by six faculty members from biology and mathematics with experience in interdisciplinary research and education.

The intellectual merit of the programme has three aspects: the integration of mathematics and biology into each of the research projects, which helps students to develop specific skills; the continued development of an interdisciplinary curricular framework to support students as they pursue their research and to encourage the development of an ongoing community of students interested in theoretical ecology; and finally, the strength of the research projects, which are all scientifically significant, conceptually interesting and timely.

COLLABORATIVE APPROACH

The UTTER programme runs for two academic years and the intervening summer session, comprising three taught courses and a summer research workshop. Professors Hristo Kojouharov and James Grover are Co-Directors of the programme. “Students in the UTTER programme complete a Bachelor’s degree in either mathematics or biology and must meet the existing requirements for their respective degrees,” they explain. “We have designed the courses taught to UTTER students so that they fulfil these degree requirements, and we also hope that these courses will be taken as elective courses by students in both programmes.” In all elements of the course, students are taught by both a biologist and a mathematician. Kojouharov and Grover have found that this holistic approach has considerable advantages. As these courses mix together mathematics and biology majors, it is important for instructors to meet these two different groups on their own terms, and having two instructors to clarify critical terms and key concepts is vital.

In the first course of the programme, students learn graphical and conceptual approaches to the construction and interpretation of mathematical models in ecology and epidemiology. These and other concepts, such as discrete and continuous time dynamical models, are introduced and a survey of classical models is presented. Students are presented with several vignettes sketching possible research projects, and form teams of three to four students to construct models that represent the verbal scenarios from the vignettes. In the spring semester of their first year, the cohort takes the second programme course, which is focused on analysis of models. Additional research topics and projects are used in this course, so that by the time it is finished, students are aware of several lines of research that they might pursue in the summer workshop. They are also asked to find other students with similar interests so that topics for the summer research workshop can be chosen, and teams identified to conduct each project. The faculty members have encouraged students to engage in deep collaboration, so that most research tasks are shared by everyone in the team. Research groups are composed of mixtures of biology and mathematics majors. In many groups, there appears to be an initial tendency for the mathematics majors to focus on model construction and analysis while...
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biology majors focus on obtaining background research and parameter estimates. Kojouharov and Grover are keen to avoid complete compartmentalisation of these tasks, so that students from all backgrounds engage in all aspects of the work.

MAINTAINING MOMENTUM

One of the biggest challenges that Kojouharov and Grover have faced is maintaining momentum after the summer research project. The first year of the programme is very intense and students receive a great deal of attention and mentoring. The second year is less structured, and was intended to accomplish two ends: provide a third course on probability and data analysis, and offer an opportunity, during the programme seminar, to continue research projects by tying up loose ends, making presentations at conferences, and writing technical reports that might turn into manuscripts.

In practice, the initiative has shown that more integrated structure and continuity of formal programme activities is needed. The first offering of the third programme course on probability and statistics did not smoothly connect to prior programme activities, and the programme seminar was not used as effectively as it could be to continue activities related to research projects. This is being addressed in new activities for the programme’s seminar, focused on helping students to develop formal about their experience in the programme and provide their own unbiased perspective of the courses, seminars and other activities.

With regards to specific student groups, the main obstacle in recruiting mathematics students into the programme has been a lack of awareness about opportunities in mathematical biology and career paths within this speciality. Few are aware of the growing job opportunities in this field, or know what specialised training is needed to pursue them. The integration of UTTER’s activities into the biology undergraduate programme faces different barriers. The traditional academic culture of biology programmes persists, in which mathematics is underemphasised compared to physics, chemistry, or engineering. A more immediate issue is that the majority of students majoring in biology aspire to attend medical school or enter other health professions. Kojouharov and Grover ascertained that it is often difficult to persuade biology students that other career paths can also provide good opportunities.

DEVELOPING YOUNG SCIENTISTS

Despite these challenges, they have successfully recruited three cohorts of students, two of which have completed the programme and the other which has just completed its first year. The UTTER scholars have had many opportunities to develop as students and young scientists.

The programme continues to develop and support students as they pursue their research.

RECRUITING SCHOLARS

Kojouharov and Grover’s group discovered that the most effective way to recruit UTTER scholars is through personal class visits, making presentations about the programme. They also found that it makes a significant difference when students from the current UTTER cohort are present during the class visits, as they can speak both through activities directly supported by the UTTER programme and other activities that have been encouraged. Several of them have participated in a number of other academic and research-related activities, including highly selective external summer research or education programmes. “All of our students have attended and presented their UTTER research projects at many regional, national, and international meetings and have received presentation awards,” Kojouharov and Grover enthuse. “However, what we are most proud of is that most members of the first two cohorts have graduated, and have been accepted to graduate studies in mathematics and biology at various US academic and health institutions.”