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Creating Undergraduate Research Opportunities Through Interdisciplinary and Intercollegiate Collaboration

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Abstract: *The Intercollegiate Biomathematics Alliance serves to bring students and faculty together different institutions to promote stronger education and research opportunities in biomathematics. One of their major ways of developing undergraduate research is through a research workshop. Projects are initiated by faculty inviting students to collaborate with them, and students are provided the opportunity to present their work at a national conference and publish in a peer-reviewed journal. We describe the details of the research workshop, and give insight into contributions to both the success and challenges of successful research with undergraduate students.*

INTERCOLLEGIATE BIOMATHEMATICS ALLIANCE

The Intercollegiate Biomathematics Alliance (IBA) was created in 2014 at Illinois State University to address the need for collaboration across institutions in the face of diminishing educational resources (Akman & Powell, 2018). Now, a state-recognized Center of Collaborative Studies, the IBA serves to bring together faculty and resources from multiple institutions to facilitate education and research in biomathematics. Institutional members of the IBA pay a fee based on institution size, and one of the benefits for students at member institutions is a fully funded research workshop and subsequent travel funding to present their research at a national biomathematics conference. This paper serves to describe the IBA Cross-Institutional Undergraduate Research Experience (CURE) and report on research projects that have initialized during the workshop. In following years, student and faculty participants will be tracked and surveyed to better understand the impacts the program has on developing future plans of students and how the workshop can better serve the needs of the participants.

CURE WORKSHOP DESCRIPTION

The CURE workshop takes place in early June each year. This time of year is chosen to avoid inhibiting students from engaging in a new project due to the stress they face during the academic year. The research that grows out of collaborations started at the workshop is intended to take place over the summer and into the following academic year. IBA institutional member students

and faculty attend the workshop free of charge (travel, food, lodging covered) but there is no direct compensation given by the IBA to the students or faculty for engaging in summer research. Faculty may choose to compensate the students if they have alternative funding sources to support undergraduate research. Non-IBA members are able to attend, but must pay a workshop registration fee and provide their own travel and lodging funding.

Faculty research talks are the foundation of the research collaboration weekend. Faculty mentors give 40-60 minutes talks on research they are currently interested in developing and how students can get involved in the research. The topic may be an continuing project for which the faculty would like to recruit more student involvement or a new project faculty would like to explore with motivated students. When faculty are unable to present in person, they present via video conference. After all faculty presentations, open time is given for students to talk to all presenters, in person or remotely, to discuss engaging in the research presented. This model benefits faculty who would like to involve students in their research by providing a wider array of motivated students. By expanding beyond drawing from just their home institution, where student interest may not coincide with the faculty area of expertise, faculty are able to connect with students who are truly interested in their work. By sharing faculty resources, students can identify a project that is of specific interest to them and are not limited to only the interests of faculty at their school. For example, students from a small school with limited computer science faculty were able to use their programming skills on a neural network research project with faculty from a much bigger school, an opportunity that would not have been available to them at their home institution. In return, faculty from the small school mentored students without as much computing background on development of epidemiology models, not requiring as rigorous of computing methods as the neural network project.

If faculty and students who embark on a project together are not from the same institution, video conferencing tools are available through the IBA, and additional travel funding for students to meet with the faculty mentor may be available. As the workshop has evolved, faculty are encouraged to share introductory literature before the workshop so students can read about potential research projects for which faculty will give presentations.

The workshop also strives to expose students to the entire research process including computational tools and scientific writing. Therefore, the weekend includes a hands-on presentation on a scientific computing tool such as Mathematica or R as well as exposure to the process and tools for writing in mathematics.

The workshop's primary purpose is to develop collaborations both among students and between students and faculty. In order to facilitate increased conversation between students from different institutions, the weekend involves scheduled social activities including an opening ice-breaker activity, a student v. faculty soccer match, and a night of bowling and pizza. We find scheduling these social events allows students to connect in a meaningful way and allows them to develop deeper relationships with other highly motivated students.

The goal is that at the conclusion of the workshop, students will decide on a research project and communicate with the faculty member directly through the summer and subsequent school year. Students are provided travel funding to present the status of their work at the Biomathematics and Ecology Education Research (BEER) Symposium in October of the same year and encouraged to submit a manuscript to the biomathematics journal Spora within a year of their participation in the workshop, with reduced open access publication charges.

APPLICATION PREOCESS

The workshop initially was open to all who wanted to participate, but we found some students did not have the appropriate background to be able to meaningfully engage in research. In addition, financial resources are limited to fully fund student participation, therefore, starting in the second year, the workshop currently limits participation to 10 student participants chosen through an application process but the number may increase as more institutions join the IBA. Students submit their transcripts and a short narrative describing their interest in the program. The only coursework requirement is completion of Calculus 1 by the time of the workshop. In order to avoid students not showing up for the program after committing, a fee is imposed for students who do not participate after a given withdraw date. Faculty from students' home institutions are asked to write a letter of support including a commitment to provide in person follow-up for students who engage in research with faculty from other institutions. Preference is given to students early in their academic career who have not had alternative opportunities to engage in undergraduate research. The students who apply are generally encouraged by faculty at their home institution who think the student will benefit from engaging in research. Students often do not know about research opportunities and the workshop allows them to get involved in research early in their academic careers, often before they would have the requisite coursework for a competitive National Science Foundation sponsored Research Experience for Undergraduates (REU). The Acceptance rate to the workshop are high for qualified students, whereas acceptance rate for paid summer research at an REU is usually below 10% (Beninson, Koski, Villa, Faram, & O'Connor, 2011). Additionally, unlike a traditional REU, the students are not required to be US citizen or permanent resident.

STUDENTS RESEARCH PROJECTS EXAMPLES AND EXPERIENCE

Examples

Project A: Epidemiology model of a wildlife disease

Two biology students participated in this study and they were equally responsible for a review of relevant literature. One student focused on studies documenting the spread of the disease including transmission modes and latency period, including standard birth and death rates for both healthy and diseased animals. The other student focused on the immunology of the disease and potential containment strategies including recent vaccination efforts. Both students contributed to the development of the mathematical model with the faculty mentors based on their discoveries in the

literature. One student did the majority of the numerical computations with the assistance of a faculty mentor and both students participated in manuscript writing with editing done by a faculty mentor. This project won an Outstanding Undergraduate Research Award for the manuscript and presentation at the Biomathematics Ecology Education and Research Symposium.

Project B: Immunology model connecting *in vitro* and *in vivo* studies

One biology student and one biochemistry did an extensive literature review of both *in vitro* and *in vivo* studies and provided guidance on important parameters to consider when considering *in vitro* to *in vivo* extrapolation and inconsistencies in studies done in each setting. The faculty mentor and students developed the mathematical model together and the majority of the numerical computations were done by the faculty mentor. The manuscript writing and editing was shared equally between the students and faculty mentor.

Experiences

Students who voluntarily elect to participate in research are often high-performing students who demand excellence of themselves in their academic work. Spending a vast amount of time reviewing literature that is not familiar to them allowed students to be more comfortable in admitting a lack of knowledge of a particular field. The discouragement of not initially understanding material was transformed to growth in the eventual understanding of a foreign topic. This growth allowed students more confidence with traditional course material that they initially struggled with and found challenging to master. Research also forced the students to think more creatively than their regular courses, since there was no roadmap to a correct answer. Considering all the factors that may not only be important in a biological system, but are also measureable, is a challenging task and requires creative thinking to determine how exactly to address relevant factors in a mathematical model. Students had to venture outside of what they had learned in their math courses to come up with appropriate ways to represent the myriad of factors they were reading about. For example, in Project A, the students noticed through using the manipulate function in Mathematica, the system was much too sensitive to the birth parameters. They reconsidered the parameter ranges for the number of offspring per breeding cycle and percent of animals breeding. They were unable to stabilize the population with modified parameter ranges and found their original values consistent within the literature. They ended up deciding to add a carrying capacity term in order to keep the population values within acceptable ranges for what was reported in the literature. In Project B, *in vitro* experiments often have an initial incubation period, after which a washing of the medium occurs. The students wrestled with how to account for the washing including considering a two-part model. The analysis of a two-part model became cumbersome so the students decided to include a step function turning different parameters on and off based on the initial incubation period. Through the time they spent grappling with how to appropriate represent the biological system mathematically, eventually, the students became better experts than the faculty in the research topic due to all the time they spent reviewing the literature and became more research colleagues than mentees to the faculty mentors.

The workshop and research experience has also influenced students' academic and career plans as well as personal growth. A transfer student, who had not connected with other students previously, found college friends for the first time at the workshop. Additionally, a highly introverted student who rarely interacted with peers in the classroom became animated and social with peers interested in similar pursuits. The decision to engage in research allows students to gain a better understanding of what graduate school may entail for them. While some may decide research is not a future direction they would like to pursue, many find it a valuable experience to solidify their decision in future career plans. After participation in research, one student from Project A changed career goals from attending a Physician Assistant program to pursuing an MD PhD for research in infectious disease. A student from Project B was unsure of post-graduation plans prior to participating in the workshop, and realized research is an important and enjoyable career path and is now pursuing graduate options in both pathology and medicine.

SUCESSES AND CHALLENGES

In its first two years, the CURE workshop had 28 student participants and 16 distinct faculty presenters, many faculty presenting in multiple years. Student academic backgrounds have included mathematics, biology, and computer science. Of the students whose research started at the CURE workshop, 11 have presented at the BEER Symposium, and 3 have published in Spora. Additionally, one of the CURE workshop participants won the Outstanding Undergraduate Research award at the BEER Symposium. Research initiated at the workshop has spanned from epidemiology models including water borne illnesses to neural networks and genetic algorithms. While the workshop has led to many connections that produced meaningful research, challenges still present themselves when engaging in research with undergraduate students, especially in when mentoring is done remotely. The biggest obstacle is always student follow through. Students may leave the workshop with every intention of following through on research through the summer, but often other activities take priority, especially work, since the research is unpaid. For students who are active participants, remote mentoring provides two unique challenges. First, for projects where data collection is involved, the student is often unable to participate in the data collection since they are not present in the data collection location. Although they may be of assistance in the analysis of the data, this can lead to secondary challenge in that fee-based computing programs may not be available to all research participants. Students may have access to a different program than their faculty mentor, requiring purchasing of the software by one party or analysis to either be done by one participant or be done in an open access software program. With the growing capabilities of open access programs, computing program boundaries will lessen, and the IBA is considering additional ways to resolve this problem through licensing agreements. Finally, students wishing to have their research be part of a senior capstone project requirement must be careful to satisfy the requirements of the project as set forth by their home institution. This can provide challenges in mentoring, especially for faculty mentors at another institution who will not know the specific requirements for completion of a capstone project. Students must be diligent in

appropriately communicating their intentions in an overlap between CURE initiated research and graduation required capstone projects.

CONCLUDING REMARKS

Overall, the CURE workshop has successfully led to many fruitful collaborations between students and faculty wishing to engage in joint research projects. It provides an opportunity where students may have none to explore a world outside of the academic classroom to delve further into their field of interest. While not a paid research position, the program is much more accessible for students of all backgrounds than an REU and allows students to engage in research who would not have otherwise thought it possible. The program strives for continued improvement in satisfying the needs of participants and help them overcome the challenges that inhibit research projects from flourishing.

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