

Undergraduate Research and Civic Engagement: Tale of Two Programs

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Towson University is a public, comprehensive Master's granting institution located just north of Baltimore City. With 14,300 undergraduate and 3,300 graduate students, Towson University, the second largest university in Maryland, is committed to undergraduate research. The College of Science and Mathematics has led the university in this area. The Dean's office provides \$20,000 each year to support undergraduate research in the form of small grants either for direct support of research or money for students to travel to conferences. As a result of these activities, students in the college have been authors or co-authors on more than 40 peer-reviewed publications and more than 250 professional presentations in recent years. There is widespread support and interest in undergraduate research on-campus. There were almost 100 undergraduate student research projects presented at the 6th Annual Student Research Expo held in the spring of 2005.

Our academic undergraduate research activities also involve the students working with the local community in substantial and significant ways; we present two examples here. First is the Applied Mathematics Laboratory, which looks to local companies and government agencies for applied mathematics undergraduate research projects and then selects a team of students to study the problem, usually for a full year. Second is the Senior Seminar, a capstone course in the Environmental Science and Studies program. This is a one-semester, required course, where the entire class works on one project of importance to the local community.

Environmental Science and Studies Capstone Experience

The Environmental Science and Studies senior class will be undertaking the program's fifth community based project in Fall 2005. This year we will be working with a local farmer to assess the environmental impact of particular farming practices. Past projects have been developed with campus Facilities Management staff and have included a feasibility study for a campus composting center for campus dining services; an assessment of and suggestions to improve the campus recycling program; an assessment of the campus landscape management program; and a study of and suggestions to reduce energy use on campus. Final reports of these projects can be found at http://www.towson.edu/ess/student_projects.htm. For facilities managers, the class presents an opportunity to gather data or information that can help them become more effective in their job. There are great advantages to developing

on-campus projects; students feel connected to the project and the clients understand the educational nature of the course. The information the clients gain is useful but not critical to the operation of their unit.

The course gives students experience in analyzing environmental problems, identifying stakeholders, and generating and evaluating potential solutions. It also provides experience in collaborative problem solving in situations where group members have different backgrounds and perspectives, and opportunities to enhance communication skills (oral and written) and critical thinking skills. The students learn to work with people from different backgrounds with different worldviews (for example, by interviewing both Deans and cleaning staff about recycling). The course also gives the students a strong sense of professional accomplishment and pride in what they have accomplished.

We find, as have others, that a service-learning course can integrate the students' academic experience (Ward, 1999); this is especially important with a multidisciplinary curriculum such as ours. Our major consists of two concentrations, Environmental Science and Environmental Studies. There is overlap in the core coursework in these two concentrations [biology, chemistry, geology, mathematics and statistics, environmental ethics, environmental health, economics, policy, geography] although those students going into environmental sciences have a little more science and those going into environmental studies have more preparation in the social sciences/humanities. Each student also completes a specialization (environmental chemistry, environmental biology, geographic analysis or environmental policy and management, for example) that provides more in-depth study in a particular discipline. The students acquire a range of perspectives through their course work and the project-based course, by drawing on these perspectives, brings the curriculum together.

The capstone class is a three-credit required course taken during a student's last year in the program. Typical enrollment for the course is in the upper teens, and keeping a class of this size engaged, coordinated and on track for a one semester project-based class is challenging. A set of 'required elements' has been developed that provide structure to the course. We have found that requiring students to submit of brief (~150 word) bi-weekly updates on their activities to be extremely valuable. These help identify potential leaders and students who are feeling overwhelmed or in need of grounding. We also use a designated "scribe" for each class meeting to maintain a record of what the class decided and when particular items are due; class notes are published on the course web site. The class develops various teams to be responsible for different components of the project. By varying the composition of the teams, students get to know their classmates quickly, and learn their strengths and weaknesses. The semester begins with a meeting with the 'client,' the person who is requesting the work. The client needs to provide the 'charge' to the class and set the focus for the semester's work. Finally, we have found that students need deadlines, and we have used a mid-term report to the client to keep them on track.

Students come into the class with a range of writing skills. In this class students edit and critique each other's work before anything is submitted to the instructor. The early editions are included when work is submitted for grading, making editing a component of a student's evaluation; this sends a clear message that editing is important. Students need to be encouraged to edit since they don't think they know what is 'correct.' With a little encouragement they realize that they can identify passages that don't "work," that is, the passages are confusing, contradictory information is being presented, the writer's meaning cannot be ascertained, or the writer is using the wrong words to describe something. Peer editing makes the students more sensitive to their own writing. When the larger project is being assembled the class develop tiers of editors. Faculty members join in the editing towards the end but by that time students have given up ownership of individual sections and all writers have also been editors.

The model for the final report enables the students to effectively integrate the project with their prior learning. Although the project focuses on a particular problem (e.g., reducing electrical usage) the final report has a section that provides the context for the problem (e.g., ecological and economic cost of different sources of energy). The context portion helps integrates the project with prior work ("So that is why we are worried about /studied X, Y and Z in a previous class"). The assessment component of the report reflects the research done during the semester (e.g., how much electricity was used by lights vs. computers). The last section involves identifying and assessing potential solutions (i.e., what changes might be made, the costs and long term benefits, both economics and ecological, of implementing the changes, etc.)

This course has only been taught by one faculty member so far (JLW) and she finds it presents a number of unique challenges. The project demands that she master new material every year and therefore requires considerable preparation. The instructor has to be willing to ask for help and to take instruction from anyone able to offer it. Before the course begins, the instructor needs a clear sense of what the students will have to accomplish to complete the final report; however one never knows exactly how a project will proceed. Keeping all of the students, with their different sets of skills, interests and abilities, engaged in the course is also challenging as is encouraging natural leadership (while preventing development of dictatorships). Students are unfamiliar (and initially uncomfortable) with such a 'goal directed' but 'no detailed instruction' course. Students have difficulty accepting the idea that they must assume responsibility and start to set the agenda. Suggesting the class develop a working outline of the 'final report' early in the semester and develop of small teams to tackle specific facets of the project make progress more definable. Grading students in a project-based course with considerable group activity is also challenging. Peer assessment is a component of a student's final grade.

The final product of the course is a written project report and a poster presentation developed for the community. Usually 8-10 posters are presented, each one highlighting a different component of the project. The students identify the themes for the different posters, create a logical order of presentation, and

design the posters. We actively recruit attendees to ensure public poster presentation is well attended. At our last class meeting we review the project, and discuss what worked, what didn't work, and what needs to be changed for future classes.

The Applied Mathematics Laboratory

The Applied Mathematics Laboratory (AML) solicits mathematical research projects sponsored by local companies and government agencies and forms teams of undergraduates in study the problems. The team of students is led by a faculty advisor from the Mathematics Department and by a co-advisor (faculty or an M.S. student) from the Mathematics Department or another department aligned with the project. The team of students works on the problem, usually for a full academic year, and provides written and oral reports to the sponsoring organizations. Students participating in an Applied Mathematics Laboratory project register for a three-credit course each semester.

The Applied Mathematics Laboratory was established in 1980. Since then, the AML has completed 16 projects for such companies as Westinghouse Electric Corporation, Bell Atlantic, Blue Cross Blue Shield, Citicorp, and Martin Marietta. A list of past projects can be found at <http://www.towson.edu/~moleary/AML>. We have had 22 different faculty members act as advisors or co-advisors on projects, including over 60% of the Mathematics Department's current tenured and tenure-track faculty (excluding mathematics education). The AML was initially modeled after the Math Clinic program at Harvey Mudd College, and is similar to the Center for Industrial Mathematics and Statistics at Worcester Polytechnic Institute.

In 2002-2003, a team of six undergraduate students led by two faculty members worked with the Baltimore City Fire Department to study their scheduling process in an attempt to reduce salary costs (Engel, May, 2005; Engel, May, O'Leary, 2005). The Fire Department was \$2 million over budget in overtime expenses, and they hoped that they could adjust their scheduling process to save money. Our students analyzed the scheduling and absence data provided by the Fire Department; then they used a combination of statistical analysis, s

imulation, and the solution of a nonlinear optimization problem to obtain a schedule that would save the city approximately \$249,000 per year in salary costs. The final results of the study were presented to Mayor Martin O'Malley and his staff in a briefing at City Hall in May 2003.

From 2003 to 2005 two teams of students worked with the Baltimore County Department of Environmental Protection and Resource Management to study water well failure rates in rural homes in the county. Our teams used statistical methods and data mining techniques to analyze patterns in the County's database of water well permits to look for patterns in water well failures.

In 2004-2005 a team of students led by two faculty members analyzed the operations of the Carroll Area Transit System in rural Carroll County. The Carroll Area Transit System provides an on-call bus service primarily to the elderly of the county. Our students analyzed the efficiency of their service, and made long-term predictions of future needs.

In 2005-2006, a team of six undergraduates will be working with two faculty members on a project sponsored by the National Institute of Justice. Our students will try to improve crime-mapping software; in particular they will try to improve upon existing algorithms that take a sequence of crimes supposedly committed by the same person, and try to determine the offender's likely "base of operation."

In contrast to the environmental science and studies capstone experience, the AML uses different faculty advisors for each project, and the role of the director of the AML is administrative. The director is first and foremost responsible for locating suitable projects each year. This is done through a combination of community outreach, personal contact, and direct mailings. Once the sponsor and the project have been identified, the director then selects the faculty member(s) who will act as the project director(s). Together this group selects the student participants. Unlike the environmental science and studies capstone experience, student participants in an AML project are selected by invitation only. Because most of our upper-level courses are small, our faculty members know which students are best able to handle these projects, and so we rely heavily on faculty recommendations to choose students.

Once the project begins, the students meet regularly with their faculty advisors. The advisors are the instructor(s) of record for the course, and have complete control over how the project proceeds. However, over the twenty-five years of the AML, various best practices have developed. We use a small space containing computers and a small library, set-aside exclusively for the AML where students and advisors can meet and work. The faculty advisors handle contact with the project sponsor, and usually arrange a sequence of meetings between the students and the sponsor so that the students can learn the background for the problem.

Our projects typically last for a full year. Although we encourage students to participate in both semesters, students are not required to do so. The students write a mid-year project report and publicly present their mid-year results to the sponsor. This is used as the basis of the student's first semester grade. At the end of the spring semester, students complete a final project report, and give a public presentation of their results to the sponsor, usually at the sponsor's offices. We use the final report to determine the students' second semester grade.

This type of undergraduate research presents a number of unique challenges. First, it is difficult to find sponsored projects of an appropriate difficulty. Further, even if a potential project is found, there may not be any faculty willing to work as the project advisors. Though the projects are interesting, the results are rarely

appropriate for publication in traditional mathematical research journals. Moreover, like the projects for the environmental science and studies capstone course, an AML project requires a substantial investment of time and effort by the faculty before the start of the course. The sponsor's expectations also present a challenge-- this course is primarily intended as a learning experience for students. Therefore the students do the actual research to solve the problem; we do not try to lead the students to the solution, but rather let the students themselves lead the way whenever practical. The sponsor needs to appreciate that the report they will receive is the work of students rather than an external consultant. Care also needs to be taken when selecting research questions. The questions selected should be both real and important, but they should not be critical to the company or government agency that is sponsoring the work.

How do you get a team of students to solve a real problem in a reasonable period of time? By getting the right team. We have found that teams of six students are ideal and provide flexibility developing subprojects. Personality issues need to be monitored and changes made to subgroups if necessary—these might not be ideal for the research but are critical for the viability of the project.

Mirroring the experiences of the environmental science and studies capstone course, we have found that in AML project deadlines need to be created and enforced. It is natural to want to let these bright and gifted students work on their own however, without regular deadlines students can get “stuck” on the problem. Undergraduates often do not know how to break a large problem up into smaller subparts. It is essential that the project advisors show the students where the natural breakpoints are in the problem, and to give them solid deadlines to meet for each portion.

There is a natural tendency for students to want to do as much research on the problem as possible, and they want to work right up to the last possible moment. However, both the interim report and the final report are significant pieces of writing. Since large portions of the report cannot be written until the research is complete, it is necessary to complete the work early enough to allow a good report to be written.

Conclusions

Projects that engage students with the community can be successfully developed and executed at larger institutions. Students completing our courses consider them wonderful learning opportunities as well as very demanding courses. There are challenges that have to be overcome in providing these courses; clearly there needs to be a good match between the instructor(s) and the class/project. Similarly, the personality dynamics of the class itself can alter the success of a particular project. It is our belief that in spite of these difficulties the courses should be continued and supported. We find that they effectively serve to transition our students from school into a work environment in which they will be responsible for the quality of the work they produce.

References

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Ancillary Materials

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Biographical Sketches

Jane L. Wolfson came to Towson University in 1998 as Director of the Environmental Science and Studies Program. Her academic background is in ecology and her research interests are in insect biology.

Mike O'Leary came to Towson University in 1998, and became director of the Applied Mathematics Laboratory in 2000. His research interests include fluid dynamics and partial differential equations.