Undergraduate Research: How Do We Begin?

Brad Bailey, Mark Budden, Michael Dorff, and Urmi Ghosh-Dastidar

“H ow do you begin to do undergraduate research?”

This is becoming an important question as more and more mathematics professors and their institutions want to provide an undergraduate research experience for their students. In this article we provide some strategies for guiding undergraduate research that were shared by the participants of the 2008 Center for Undergraduate Research in Mathematics (CURM) workshop at Brigham Young University in Provo, Utah.

Like effective teaching, successful undergraduate research is based upon foundational ideas that should be adapted and expanded to fit the talents of the professors and the needs of the undergraduates.

Get students interested. A good visual aid can help students become interested, even enthusiastic, about a problem. For example, one faculty member uses soap bubbles on wire-frame cubes to illustrate minimal surface areas. Students might not be willing or able to tackle hard problems at first, but making their introduction to the project fun and exciting can make them more committed to overcoming the hard work that lies ahead. Ideally, they will start taking the initiative to solve more difficult problems on their own.

Present background material. The time a professor spends presenting background material depends upon the research topic. However, if a professor spends too much time, there will be little time for doing research. Generally, we find that the presentation of background material should not exceed 25% of the time.

There are several approaches to presenting the material. Some professors choose to prepare a set of notes for their students. They provide these notes to the first group of research students and extend or expand the notes each year with each new group of students. As it is important to carefully and accurately prepare anything the professor gives to his students, writing and revising such a set of notes may be very time consuming. However, one potential long-term benefit is that these extensive notes may become early drafts of a book or part of a book that the professor later intends to publish.

A second approach is to give the students articles to read. Some of the more experienced members of the workshop noted that research articles are written for profession-
While it may be tempting to give students the whole problem at the beginning of the project, this may overwhelm and discourage them. Instead, over the course of time, the mentor may choose to give them several small problems that are part of a larger project, or even a series of problems that build or lead toward the project’s goals. This process of problem solving provides students the insight to formulate and prove a theorem.

For example, if one of the goals of the project is to prove an existential theorem, the advisor may start with the students working in a simplified setting in which they can actually find or solve for the “object” that exists, thus giving the students the opportunity to realize that these “objects” always exist (or exist under certain conditions). This approach will lead them to discover, and ultimately prove, the result they were looking for.

Develop student independence. Continuous encouragement to pursue new avenues promotes student independence. Many students will be resistant to doing something new or something they are not “good” at. In one example given by a faculty member, the professor had a group working on a problem in discrete mathematics, and the students were making decent progress early on. However, after a week or two, the results stopped coming. He repeatedly urged the group to write a computer program to aid in solving the problem, but the students were extremely resistant. The faculty member was persistent and convinced them to write the code, after which, they gained the necessary insight to reestablish their progress.

Preparing a list of expectations and presenting it to the students in the beginning of the research period is also beneficial. For example, the professor may want the students to know LaTeX well enough to write up their findings and effectively communicate with the research group via e-mail. The faculty member may also urge students to type their results as they work. This forces them to think carefully about their notation as well as the wording and logic of their proofs. It frequently leads to stronger, more eloquent proofs and can generate more research avenues. At the end of the project, these notes can be compiled into a final paper. Since the paper was prepared slowly over a long period of time, the overall quality will be higher than if the students waited until the end to write up the results. Regular presentation of their results, either to the advisor or to the entire research group also advances their confidence level and communication skills.

Moreover, the list of expectations may also include the average amount of time per week that each student is expected to commit to the project. The mentor may require his students to submit a brief report each week about their work and findings for that week. Writing such reports not only benefits the students, it also provides the professor insight into the students’ understanding of the process.

Student frustration. At times, students may feel they are no longer making progress and become frustrated. Students should be told in advance that this will occur — that frustration is okay and happens to everyone. In trying to overcome frustration, the advisor may choose to work through hurdles with them, asking questions along the way. It is important that they become involved in this process and not just reply “yes, I understand” to the professor’s questions. They should be able to explain their answers and their understanding of the important concepts and techniques. If the research problem is too complex for the student to solve, the professor may provide a simpler version of the original problem.

The research problem. As the mentor has worked through the previous steps, it is probably useful to point out potential research problems. For example, while reading through an article with the students, the pro-
The Pea and Sun

by Lawrence M. Lesser

(This may be sung to the tune of George Harrison’s ‘Here Comes the Sun’)

Banach–Tarski — come break a ball into six pieces:
Reassembled — that first ball sure increases!

The pea and sun,
A 2-for-1, and I say, it’s all right.

Banach–Tarski — it is a mathematics wonder:
Banach–Tarski — could it maybe end world hunger?

The pea and sun,
A 2-for-1, and I say it’s all right.

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This workshop was run by the Director of CURM, Michael Dorff, (mdorff@math.byu.edu) Brigham Young University. Authors for this piece comprise: Brad Bailey (bbai-ley@ngcsu.edu) North Georgia College & State University, Mark Budden (mark. budden@armstrong.edu) Armstrong Atlantic State University, and Urmi Ghosh-Dastidar (ughosh-dastidar@citytech.cuny.edu) New York City College of Technology. CURM is supported by the NSF grant DMS-0636648.