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## Improving Research Culture at the Undergraduate Level

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This document must be considered as a series of recommendations, not an official or mandatory guideline from the University of Puerto Rico. This is the result of hard work and analysis from researchers interested in improving the research culture at the undergraduate level in the Department of Chemical Engineering.

### Introduction

During the course of K-12 education students are dependent on and supported by the structure of a curriculum. This structure provides them confidence and a sense of accomplishment. As students in college advance in their undergraduate studies this structure begins to fade and it is up to them to figure out the individual road they want to pursue. Whether a student wishes to start his own company, enter a professional school or become a scientist, he or she must figure out the series of steps needed to be better prepared to get to their goal. In the context of a teaching institution that is slowly transitioning to becoming a research one, the need to create a structure or “road map” towards developing a research culture early on is critical to allow those students that want to become scientists to have a clear view of the path they need to follow. For over 80 years the Department of Chemical Engineering has been successful in providing the roadmap to becoming a successful professional engineer, and as we continue to move forward with technological advances and expansion of the boundaries of knowledge we must provide the appropriate environment for our young “potential scientists” to develop. The course series presented here intends to accomplish exactly the latter. Highly creative and scientifically curious students may be unsure as whether they have the capabilities to become a professional scientist because they ignore that as they did not become engineers overnight the path to become a scientist is also a structure and rational endeavor that requires time investment and self determination. It is our goal to

create a concrete path for undergraduate students at the UPRM to follow in order for them to become successful scientists.

## **Roadmap to a Competitive Undergraduate Research (UR) Experience**

### **Step 1: Spring Second Year (May)**

- General orientation about UR organized by coordinators: description of recommended roadmap and advisor selection procedures
- Milestone: Provide information on research groups and activity of the department

### **Step 2: Summer**

- Milestone: Advisor Selection
- Students are expected to visit and interview active researchers of the department
- The choice of advisor should be based on the person's: accomplishments in teaching and research, enthusiasm for advising students, experience in directing other undergraduate and graduate students, management and organization of his or her research group, reputation for setting high standards in a congenial atmosphere, and compatible personality.

### **Step 3: Third Year Semester I**

- INQU4105: Entering Research in Chemical Engineering Part I
- Thematic Outline: (1) Finding a research experience, (2) The nature of chemical science and engineering, (3) Searching the literature for scientific articles, (4) Reading scientific articles and mentoring styles, (5) Your research group's focus, (6) Establishing goals and expectations with your mentor, (7) Who's who in your research group, (8) Documenting your research, (9) Defining your hypothesis or research question, (10) Designing your experiments, and (11) Research proposal review draft and presentations
- Milestone: Submit a research proposal at the end of the semester

### **Step 4: Third Year Semester II**

- INQU4106: Entering Research in Chemical Engineering Part II (Co-requirement INQU4998 and INQU4105 Entering Research in Chemical Engineering Part I)
- Thematic Outline: (1) Scientific communication, (2) Research project outline and science abstract, (3) Mentoring relationship reflections, (4) Peer review of general public abstract, (5) Science and society, (6) Research ethics, (7) Making effective scientific presentations, (8) Peer review presentation, (9) Funding/Grants – the future of your project, (10) Peer review of mini-grant, and (11) Research experience reflections
- Milestone: Poster or Oral Presentation at the Undergraduate Research Symposium

### **Step 5: Fourth Year Semester I**

- Continuing research activity - INQU4998 or INQU5995



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- Milestone: Oral or poster presentation outside of the department

**Step 6:** Fourth Year Semester II

- Continuing research activity - INQU4998 or INQU5995
- Milestone: Oral or poster presentation outside of the department

**Step 7:** Fifth Year Semester I

- Getting published - INQU4998 or INQU5995
- Milestone: Paper draft and journal selection

**Step 8:** Fifth Year Semester II or your last semester

- Getting published - INQU4998 or INQU5995
- Milestone: Final manuscript and peer review process
  - Final manuscript consists of a report following the IMRAD research paper format and recommendations of your advisor (see reference section).
  - The student should deliver a short oral presentation at the Department's research symposium.
  - Upon satisfactory submission of the manuscript and presentation the student will receive an honor research certificate issued by the department and undergraduate research coordinators.
  - The student is responsible of providing evidence of accomplishing these milestones to the undergraduate research coordinators.

Note: Students are encouraged to apply for REU and other undergraduate research opportunities at other universities during summer break. These programs should be selected based on their competitiveness and prestige. Students will need to offer a convincing argument for why they are interested in that particular program, and offer proof that they are capable of contributing to the research process. It is noteworthy; that these opportunities are highly appealing in an undergraduate student's résumé and contribute to their professional development.

**Table 1: Recommended Roadmap Summary**

Semester	Course Credit / Workshop	Expected Milestone
Spring Second Year (May)	General Orientation about UR and Advisor Selection Procedures	Awareness of Research Culture at the Department
Summer	---	Advisor Selection

Semester	Course Credit / Workshop	Expected Milestone
Third Year Semester I	INQU4105: Entering Research I	Research Proposal
Third Year Semester II	INQU4106: Entering Research II	Poster / Oral Presentation at Research Symposium
Summer	INQU4998 or INQU5995 or REU	Research
Fourth Year Semester I	INQU4998 or INQU5995	Poster / Oral Presentation outside the Department
Fourth Year Semester II	INQU4998 or INQU5995	Poster / Oral Presentation outside the Department
Summer	INQU4998 or INQU5995 or REU	Research
Fifth Year Semester I	INQU4998 or INQU5995	Paper Draft and Journal Selection
Fifth Year Semester II or your last semester	INQU4998 or INQU5995	Final Manuscript and Peer Review Process, Final Oral Presentation

### Bullet Points for the Students: Benefits of Undergraduate Research

- Doing problem sets and lab classes is *not* the same as doing *science*. Undergraduate research introduces you to the *actual* scientific process.
- Undergraduate research helps you test-drive a particular type of science or engineering. How else would you know if you would like to ultimately work on nanotechnology, or bioengineering, or (fill in the blank)?
- Working in a research group naturally puts you under the care of a grad student / postdoc / faculty mentor. Their advice for your academic career is valuable.
- Research students usually get fantastic grad school letters of recommendations from advisers who can write substantially about a student's scientific potential.
- If you're able to take a project a bit further, the experience of publishing a paper or giving a conference talk is priceless.
- The most important thing is to understand how research works: the creative process, troubleshooting, the way questions are posed and the different approaches to a solution.
- Mentors provide more than advice about what the next step in your career is. They are role models to try to emulate, provide a structure of support, and pass on 'good research habits' along the way. Mentors needn't be faculty members —



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department staff, postgraduate students, and advanced undergrads all have useful things to share with students who are just embarking on their scientific careers.

- Academia is a fantastic field to work in — but don't underestimate its potential to be cutthroat and competitive at times.
- Use your undergraduate years to develop a set of skills that may either be essential in grad school, or that might otherwise make you unique. These skills may include a strong background in certain areas of mathematics, a knack for software programming, or even knowing how to make a nice figure for a paper. It's a bit hard to predict what will be important down the road, so don't be afraid to branch off and spend a bit of time doing things outside the mainstream.
- Undergraduate research is a high-impact educational practice that is correlated with student success.
- Your undergraduate research experience will be an important piece in the economic growth and development of Puerto Rico. We need highly creative and open minds to come up with novel ideas to support the socioeconomic development of the Island. During the formation process as a scientist you will, not only directly impact our country's development but also obtain skills that will help improve and expand research opportunities to other students. Consequently, you will be part of an improved and well-established research culture.

### **Profile of a Highly Competitive Undergraduate Student Seeking Graduate School**

- GPA 3.30 or more
- 2-3 years of undergraduate research experience (preferably under a same theme or research area)
- 1-2 REU opportunities at national universities
- 3 oral presentations and posters at local and national conferences
- 1 publication at a peer-reviewed journal
- Actively involved in outreach activities (to the community, to the university, to Puerto Rico)
- Active member and leader of local organizations, such as AIChE, SHPE, etc.
- Excellent oral and writing skills in English
- Excellent scores in GRE

### **References**

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