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# A PLAN TO INCREASE UNDERGRADUATE RESEARCH AND STUDENT DIVERSITY IN THE BOTANY DEPARTMENT OF A LARGE RESEARCH UNIVERSITY

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## **Why focus on undergraduate research:**

The process of arriving at new knowledge is frequently more important than the knowledge itself. This is certainly true in science education. Students with the greatest chances of succeeding in science learn to DO science early. In the context of a research university, doing frequently means participating in research activities.

A number of national organizations have recommended the expansion and improvement of efforts to include students in college/university research (CUR, 2001; NSF, 1996; Sigma Xi, 1989). The Boyer Commissions (1996) first recommendation for research universities is to make research-based learning the standard.

Previous authors suggest that undergraduate research experiences can be highly effective tools for recruiting under-represented groups (DeWitty, 1994; Gregerman, 1999; Mabrouk and Peters, 2000; Rodriguez, 1999). This is especially important since many such groups have not received the same exposure to research as others (ACE 1985; NSF 1990; PHERP, 1991). Brazziel and Brazziel (1997) noted quality undergraduate research experiences as a characteristic of institutions producing high numbers of minority science and engineering doctoral starts. Likewise, the recommendations of several national organizations have included the greater inclusion of women and minorities in such activities (Boyer Commission, 1996; NSF, 1996; Sigma Xi, 1989).

Traditionally under-represented groups, women and racial minorities, account for the majority of students in higher education. Therefore, aside from the obvious social benefits of gender/racial equality, it is critical to the national scientific infrastructure that under-represented groups be included in research activities. Diversity in the research setting ensures diversity of thought, which, in turn, translates into scientific innovation. Thus, maintaining a diverse population of scientists promotes a higher quality of life for everyone. The purpose of this report is to describe proposed changes to the undergraduate curriculum of the Department of Botany at North Carolina State University (NCSU) designed to increase the amount of undergraduate research and student diversity.

## **Program Assessment:**

BO 102, Introduction to Research, was a course developed to address the need for botany undergraduate majors to participate in doing science. It was thought that participation in research would increase the likelihood that some would continue on into a science career. It would also help prepare students to understand future scientific issues better than citizens who lack a direct research experience.

BO 102 currently is a requirement for all botany undergraduate majors. As originally conceived, students would take BO 102 while they are freshmen or sophomores as the second course in a required three-course sequence.

**BO 101; 1hr.  
PERSPECTIVES ON BOTANY**

**BO 102; 1hr.  
INTRODUCTION TO RESEARCH**

OR

**TEACHING EXPERIENCE  
UNDERGRADUATE  
RESEARCH**

During BO 101, students are introduced to Botany faculty, post-doctoral scientists, and graduate students and their research programs. The major requirement of students taking 102 is to prepare and orally present a short (4-5 page) proposal of a research study designed to address a single question of narrow focus. This proposal must include a clear statement of the question, an experimental hypothesis, description of materials and methods, and a minimum of five journal article references. Students are instructed to work in teams of 2-3 to develop their proposals with the help of Botany faculty and/or graduate students. The following list of topics from the BO 102 syllabus for 2000 shows that instruction was included on the content of former student proposals, structure of botanical journal articles, and use of computer based literature searches. Additionally, students attended the annual meeting of the NC Acad. Sci. to see the research results of undergraduates from across NC.

DATE	ACTIVITY
1/25	Course orientation
2/1	Review former student proposals
2/8	Discuss a botanical journal article
2/15	Select proposal topics; Form working groups
2/22	Computer based literature search
3/7	Working group progress reports I - Graded
4/1	Attend NCAS; Interview undergraduate
(Saturday)	student presenter
4/11	Working group progress reports II - Graded
4/25	Proposal presentations Graded (continued next mt. if necessary)
5/2	This meeting will be held only if there are proposals needing to be presented.

After completing BO 102, students complete the required three-course sequence by participating in either a teaching or research experience.

While the goals of BO 102 are appropriate, the course has not been received well by undergraduates and it has not been an effective mechanism for getting undergraduates into research. Following completion of BO 102, most have not chosen a research experience to complete the three-course sequence. This observation led us to examine the course more carefully.

Upon examining BO 102, we found that one problem reducing the effectiveness of 102 related to student demographics. Although the course was intended for freshmen or sophomores, the majority of students who took the course were juniors or seniors. Many of these older students had declared botany as a second major late in their student career. Typically, these older students who were double majoring did not have time to participate meaningfully in research after completing 102. Additional problems related to the structure and content of the course. Comments from former 102 students suggested that they did not receive enough appropriate help in selecting proposal topics and developing the proposal, instruction in the mechanisms of research, or instruction in presentation skills. Some students indicated that botanical research is an isolating experience because it requires so much intense effort. As a result, student impressions of research were negative. It might be that 102 had actually discouraged some students from doing research. Our conclusion was that BO 102 must change if it is going to stimulate students to attempt scientific research and before it can attract under-represented student groups.

**Finding Solutions:**

After recognizing problems with BO 102, we sought to identify potential solutions. For this purpose, we obtained surveys concerning the support of undergraduate and high school student research that had been administered through the Education Committee of the American Society of Plant Biologists (see appendices 1 and 2). It was an e-mail survey that had been completed by 531 researchers in plant biology all around the country. The responses had been analyzed to ascertain the major issues surrounding student research from the mentor perspective (Coker & Davies, 2002). After reviewing the experiences of this large pool of researchers, we reached four main conclusions relating to student research support and BO 102:

1. Get students involved in research earlier in their college careers.
2. Give students more direction.

3. Time is the biggest faculty concern in supporting student research.
4. Student research can be a highly effective recruiting tool.

The first two conclusions were strong trends among those who reported having successes with student researchers. The third was the major faculty drawback, which must be addressed for student research experiences to improve/increase. The final conclusion was voiced strongly by a small number of survey respondents. As one survey comment stated, It (undergraduate and high school research) ensures the development of minorities in science.

During the summer of 2001, we participated in a workshop titled "Diversity in the Classroom" to increase our understanding of the concerns of groups typically under-represented in our botany classes. We began this workshop thinking that effective teaching which addresses a variety of learning styles should be appropriate for attracting and retaining minorities. We learned that that was not necessarily the case.

Our workshop experiences led us to the following conclusions:

1. Classroom culture is just as important, if not more, than effective teaching for attracting and retaining women and racial minorities in science.
2. The perceived emphasis that science places on individual competitiveness causes many students to abandon their science major. This is especially true of minorities.
3. An emphasis on the cooperative nature of research can help a great deal in decreasing student anxiety and the feeling of isolation.

The changes that we recommend below address many of the issues indicated by the results of the ASPB survey and the diversity workshop.

### Recommended changes to BO 102:

**Get students involved in research earlier** - To be effective in getting students to participate in undergraduate research, BO 102 must attract freshmen or sophomores, young students who would have time before graduation to participate in research. We propose to promote botany as an undergraduate major with young students in NCSU's First Year College (FYC). The goal of this promotion will be to present botany as a viable choice of majors that can lead to professional schools, graduate schools, or jobs after a B.S. degree. Part of this promotion will center on undergraduate research in the Botany Department, including BO 102, as an important learning experience and resume-builder. Other highlights will include our department's excellent teachers and contemporary courses. Four Botany faculty and two undergraduates spoke with 12 FYC students last November and follow-up emails were sent to each of the 12 FYC students. We plan to continue interacting with FYC students every fall semester. We also intend to cooperate with NCSU's office of Diversity Programs in our attempts to recruit young undergraduate majors. Finally, in the BO 102 course, when counseling students, we will emphasize the advantages of doing research early in one's undergraduate career.

**Give students more direction** - Dr. Patricia Mabrouk (Dept. of Chemistry, Northeastern University, Boston) is known nationally as a successful mentor of undergraduate researchers (Mabrouk, 2000; Mabrouk and Peters, 2000). We visited her laboratory to discuss activities of her program that have been particularly useful in structuring effective undergraduate research experiences. We hope to integrate these practices into BO 102 where we expect they will improve learning experiences and draw more students into research programs.

MABROUKS ACTIVITY	IMPLEMENTATION IN BO 102
Carefully crafted research projects	At the beginning of the semester, give students specific questions as subjects of their proposals. Previously, students developed their own proposal ideas.
One on one mini-lectures	Frequent meetings with research mentor to discuss the step-by-step progress of the proposal
Participation in weekly research group meetings	Each student will regularly attend the meetings of one departmental research group.
Opportunities for presentation & publication	Students attend NC Acad. Sci. meeting to see undergraduates present their research; orally present proposal to BO undergraduate majors

**Emphasize the importance of cooperation in research** - Rather than being an isolating force, research should increase cooperation between diverse workers. This will become apparent to students as they attend weekly meetings of research groups in the department. Additional awareness of the importance of cooperation will come from activities during the regular BO 102 class meetings that have not previously been part of the course. These classroom activities will include panel discussions involving researchers from a variety of academic positions (undergraduate, graduate student, post-doc, etc.), genders, ages, races, and nationalities. Panelists may be recruited from other science departments. Discussions will address topics other than the content of the individuals' research: reasons for individuals entering and remaining in science, effective teaching and mentoring, individuality *vs.* cooperation in science, *etc.* Small group discussions among BO 102 students relating to these issues will also be attempted.

**Maximize opportunity for publication of undergraduate research** - The internet reveals that there are currently numerous hard copy and electronic journals dedicated to undergraduate research. One class assignment will be for each student team to survey the tables of contents for five of these journals and select one paper to orally summarize in class.

### Measures of success:

To test the effectiveness of our approach to improving the undergraduate research experience and student diversity in the Botany Department, we will use three approaches.

1. monitor the number of majors doing research.
2. track changes in student attitudes/understanding of science through pre- and post-research surveys and panel discussions.
3. monitor the number of minorities that associate with the department.

The first and third assessment methods are very rudimentary and obvious. Through the pre- and post-surveys and discussions, though, we will explore the undergraduate experience much more deeply. We are developing questionnaires for the student surveys (see Appendix 3).

In the end, we feel that success of our proposed changes will mean an increase in the number of undergraduates doing research, the number of traditionally under-represented groups majoring in botany, measurable positive changes in student attitudes concerning research, and a better education for everyone.

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### Appendix 1 ♦ Frequencies of ASPB member comments regarding the potential advantages of supporting undergraduate (UG) and high school (HS) research (from Coker and Davies, 2002).

<b>Personal Rewards (for mentors)</b>	<b>UG</b>	<b>HS</b>
Mentoring and teaching	56	18
Fun / Pleasure / General personal reward	9	6
Seeing students present (and win awards for) their research	5	5
Seeing students go on to careers in science	4	2
Satisfying a moral obligation (students justify the existence of faculty)	2	0
<b>Intellectual Rewards (for mentors)</b>		
Questions of young researchers force the re-evaluation of ideas	11	4
Influx of new/innovative ideas	8	1
<b>Improved Recruiting/Communications</b>		
Recruitment of high-quality graduate students	16	0
Knowing students personally helps improve teaching/mentoring skills	5	2
Recruitment of high-quality undergraduates	4	5
Recruitment of women and minorities into science	4	2

Networking	2	1
Usefulness of seeing how grad students perform in instructing students	2	0
Source of skilled personnel for future positions in the same faculty lab	2	0
<b>Research Benefits</b>		
Add to lab productivity	46	1
Create an energetic and enthusiastic lab environment	41	12
Bring an unbiased view of science to the lab	9	0
Cheap work force (can be "paid" with course credit, work study, etc.)	8	3
Workers for jobs that mentors would consider boring or repetitive	5	5
Workers that are more willing to try novel and/or risky projects	5	3
Many younger students offer skills in computer technology	1	2
Allows research even with a heavy undergraduate teaching load	1	0
<b>Undergraduate or High School Student Benefits</b>		
General learning/interest/motivation in plant biology	44	19
Assistance in career choices	21	6
Motivation/opportunity to do graduate degrees	14	0
Become co-author on a published research paper	9	4
Training in laboratory techniques	8	3
Reinforced classroom learning (relate theory to practice, etc.)	8	2
Build skills in teamwork	6	0
Motivation to do honors degree	3	0
Job market advantage	3	0
Grow as independent critical thinkers	2	2
Build self-confidence	2	1
<b>Graduate Student and Post-Doc Benefits</b>		
Improve teaching and mentoring abilities	7	1
Assistance on research projects	3	0
Motivated to do more, if only to stay ahead of the younger students	1	0
<b>Private Industry Benefits</b>		
Prescreen for potential employees	1	0

**Appendix 2** Frequencies of ASPB member comments regarding the potential disadvantages of supporting undergraduate (UG) and high school (HS) research (from Coker and Davies, 2002).

<b>Student-Based Disadvantages</b>	<b>UG</b>	<b>HS</b>
Short time commitment of students	41	21
Insufficient background in science	8	22
Lack of motivation/interest	7	7
Difficulties working independently/reliably	7	5
Scheduling problems	6	3
Waste of materials / Damage of equipment	6	2
Immaturity	1	9

Transportation problems	1	2
Safety concerns	1	2
Overbearing parents	0	4
<b>Mentor-Based Disadvantages</b>		
Time consuming for mentor	84	45
Can be less productive in terms of publishable data	13	7
Requires a great deal of work (to train students, etc.)	9	15
Costly financially / Insufficient funding for students	8	2
Instructing students is not rewarded professionally	5	1
Project is peripheral to labs main interests	1	2
Difficulties relating to younger students	1	1
Legal hassles with accident insurance coverage	1	0
Looked down upon by academic peers	1	0

### Appendix 3 Pre- and post-research student questionnaires.

#### EXIT QUESTIONNAIRE FOR STUDENTS WHO HAVE NOT DONE UNDERGRADUATE RESEARCH

The Department of Botany is gathering information that will contribute to improvement of the undergraduate curriculum. As part of this effort, we need you to complete the following questionnaire. It will probably take about 30 min. Thanks.

**Name (Print):** \_\_\_\_\_

**Today's date:** \_\_\_\_\_

Female \_\_\_\_\_ Male \_\_\_\_\_

Approx. Overall GPA: \_\_\_\_\_

In what state did you attend all/most of your high school? \_\_\_\_\_

Approximately how many students were in your high school graduating class? \_\_\_\_\_

Did you take a high school biology course? (yes/no) \_\_\_\_\_

In high school, did you learn as much about plants as you did about animals? (yes/no) \_\_\_\_\_

What are your long-term career goals?

Do you know what job you will be taking immediately after leaving NCSU? If you do, indicate what organization your job is with and a brief description of your position.

Briefly explain why you majored in Botany. If you are not majoring in Botany, explain why you are taking this questionnaire.

ANSWER THE NEXT FOUR QUESTIONS ONLY IF YOU ARE A BOTANY MAJOR.

For how many years were you a Botany major? \_\_\_\_\_

Did you get what you wanted to get out of your Botany major? (yes/no) \_\_\_\_\_

How satisfied are you that you are graduating with a Botany major (1=not satisfied at all, 5=verysatisfied)? \_\_\_\_\_

Did your Botany major prepare you, at least moderately well, to understand how scientists think and how scientific knowledge is developed ? (yes/no) \_\_\_\_\_

Have you completed BO 101, Perspectives on Botany? (yes/no) \_\_\_\_\_

Have you completed BO 102, Introduction to Research? (yes/no) \_\_\_\_\_

Do you want to understand how scientists think and how scientific knowledge is developed? (yes/no) \_\_\_\_\_

In your opinion, how well do you have the understanding of scientific thinking referred to in the previous question? (1=not well at all, 5=very well, indeed) \_\_\_\_\_

How necessary for human welfare is scientific research is? (1=absolutely unnecessary, 5=essential for the worlds well-being) \_\_\_\_\_

Rate your understanding of research as a process. (1= don't understand it at all, 5= understand it very well) \_\_\_\_\_

Do you want to do research in the future? (yes/no) \_\_\_\_\_

Do you want to become a professional scientist? (yes, no) \_\_\_\_\_

How confident are you that you could become a professional scientist should you ever want to do so? (1= not confident at all, 5=very confident) \_\_\_\_\_

What benefits could a student gain by doing undergraduate research?

Rate your attitude about not having done undergraduate research. (1= very glad I didnt do it, 5= very sorry I didnt do it) \_\_\_\_\_

Explain why you chose not to do undergraduate research.

In your opinion, how many hours per week and how many semesters are required for a research experience beneficial to undergraduates?

Although you have not done undergraduate research, answer this question as well as possible. What characteristics (personal, intellectual, experiential) make a faculty/post-doc/graduate student a good research mentor?

In your opinion, are there certain personality or intellectual characteristics that distinguish successful researchers from others? If so, what are these characteristics? Which of these characteristics do you have?

How satisfied are you so far with your academic experiences in the Dept. of Botany? (1=completely dissatisfied, 5=completely satisfied) \_\_\_\_\_

How comfortable have you been with your experiences in the Dept. of Botany? (1=totally uncomfortable, 5=very comfortable) \_\_\_\_\_

**EXIT QUESTIONNAIRE FOR STUDENTS WHO HAVE DONE UNDERGRADUATE RESEARCH**

The Department of Botany is gathering information that will contribute to improvement of the undergraduate curriculum. As part of this effort, we need you to complete the following questionnaire. It will probably take about 30 min. Thanks.

**Name (Print):** \_\_\_\_\_

**Today's date:** \_\_\_\_\_

Female \_\_\_\_\_ Male \_\_\_\_\_

Approx. Overall GPA: \_\_\_\_\_

In what state did you attend all/most of your high school? \_\_\_\_\_

Approximately how many students were in your high school graduating class? \_\_\_\_\_

Did you take a high school biology course? (yes/no) \_\_\_\_\_

In high school, did you learn as much about plants as you did about animals? (yes/no) \_\_\_\_\_

What are your long-term career goals?

Do you know what job you will be taking immediately after leaving NCSU? If you do, indicate what organization your job is with and a brief description of your position.

Briefly explain why you majored in Botany. If you are not majoring in Botany, explain why you are taking this questionnaire.

ANSWER THE NEXT FOUR QUESTIONS ONLY IF YOU ARE A BOTANY MAJOR.

For how many years were you a Botany major? \_\_\_\_\_

Did you get what you wanted to get out of your Botany major? (yes/no) \_\_\_\_\_  
How satisfied are you that you are graduating with a Botany major (1=not satisfied at all, 5=verysatisfied)? \_\_\_\_\_

Did your Botany major prepare you, at least moderately well, to understand how scientists think and how scientific knowledge is developed? (yes/no) \_\_\_\_\_

Have you completed BO 101, Perspectives on Botany? (yes/no) \_\_\_\_\_

Have you completed BO 102, Introduction to Research? (yes/no) \_\_\_\_\_

Do you want to understand how scientists think and how scientific knowledge is developed? (yes/no) \_\_\_\_\_

In your opinion, how well do you have the understanding of scientific thinking referred to in the previous question? (1=not well at all, 5=very well, indeed) \_\_\_\_\_

How necessary for human welfare is scientific research? (1=absolutely unnecessary, 5=absolutely essential) \_\_\_\_\_

Rate your understanding of research as a process. (1=dont understand it at all, 5=understand it very well) \_\_\_\_\_

How confident are you that you could become a professional scientist? (1= not confident at all , 5= very confident)? \_\_\_\_\_

Do you want to do research in the future (yes/no)? \_\_\_\_\_

Do you want to become a professional scientist (yes, no)? \_\_\_\_\_

What benefits do students gain by doing undergraduate research?

Rate your attitude about having done undergraduate research. (1=very sorry I did it, 5=very satisfied I did it) \_\_\_\_\_

Explain why you chose to do undergraduate research.

In your opinion, how many hours per week and how many semesters are required for a research experience beneficial to undergraduates?

What characteristics (personal, intellectual, experiential) make a faculty/post-doc/graduate student a good research mentor?

Are there certain personality or intellectual characteristics that distinguish successful researchers from others? What are these characteristics? Which of these characteristics do you have?

How satisfied are you with your academic experiences in the Dept. of Botany? (1=completely dissatisfied, 5=completely satisfied) \_\_\_\_\_

How comfortable have you been with your experiences in the Dept. of Botany? (1=totally uncomfortable, 5=very comfortable) \_\_\_\_\_

Did you do undergraduate research with a Department of Botany mentor (yes, no)? \_\_\_\_\_ If No, then in what department does your mentor reside? \_\_\_\_\_

Considering all factors, how would you rate your undergraduate research experience (1=definitely not good; 5=very good)? \_\_\_\_\_

Would you recommend undergraduate research to other students? \_\_\_\_\_

Check each activity below that you did as part of your research experience.

- \_\_\_\_\_ made observations that led to a hypothesis
- \_\_\_\_\_ formulated hypothesis based on observations
- \_\_\_\_\_ designed experiments
- \_\_\_\_\_ wrote grant proposal
- \_\_\_\_\_ performed experiments
- \_\_\_\_\_ collected data
- \_\_\_\_\_ analyzed data
- \_\_\_\_\_ interpreted results of experiment
- \_\_\_\_\_ concluded whether or not a hypothesis was supported by experimental results
- \_\_\_\_\_ presented research orally
- \_\_\_\_\_ presented research as poster
- \_\_\_\_\_ presented research in a manuscript submitted for pre-publication review
- \_\_\_\_\_ presented research on the internet
- \_\_\_\_\_ non-experimental, routine tasks (dish washing, photocopying, etc.)

What were the major rewards of your research experience?

What were the major difficulties/frustrations of your research experience?

## STUDENT PRE-RESEARCH QUESTIONNAIRE

The Department of Botany is gathering information that will contribute to improvement of the undergraduate curriculum. As part of this effort, we need you to complete the following questionnaire. It will probably take about 30 min. Thanks.

**Name (Print):** \_\_\_\_\_

**Today's date:** \_\_\_\_\_

Female \_\_\_\_\_ Male \_\_\_\_\_

FR \_\_\_\_\_ SO \_\_\_\_\_ JR \_\_\_\_\_ SR \_\_\_\_\_

Approx. Overall GPA: \_\_\_\_\_

In what state did you attend all/most of your high school? \_\_\_\_\_

Approximately how many students were in your high school graduating class? \_\_\_\_\_

Did you take a high school biology course? (yes/no) \_\_\_\_\_

In high school, did you learn as much about plants as you did about animals? (yes/no) \_\_\_\_\_

What are your long-term career goals?

Briefly explain why you majored in Botany. If you are not majoring in Botany, explain why you are taking this questionnaire.

Have you completed BO 101, Perspectives on Botany? \_\_\_\_\_

Have you completed BO 102, Introduction to Research? \_\_\_\_\_

Do you want to understand how scientists think and how scientific knowledge is developed? (yes/no) \_\_\_\_\_

In your opinion, how well do you have the understanding of scientific thinking referred to in the previous question? (1=not well at all, 5=very well, indeed) \_\_\_\_\_

How necessary for human welfare is scientific research? (1=absolutely unnecessary, 5=essential for the world's well-being) \_\_\_\_\_

Rate your understanding of research as a process. (1= don't understand it at all, 5= understand it very well) \_\_\_\_\_

Do you want to do research in the future? (yes/no) \_\_\_\_\_

Do you want to become a professional scientist? (yes, no) \_\_\_\_\_

How confident are you that you could become a professional scientist? (1= not confident at all, 5=very confident) \_\_\_\_\_

What benefits could a student gain by doing undergraduate research?

In your opinion, how many hours per week and how many semesters are required for a research experience beneficial to undergraduates?

Although you have not done undergraduate research, answer this question as well as possible. What characteristics (personal, intellectual, experiential) make a faculty/post-doc/graduate student a good research mentor?

In your opinion, are there certain personality or intellectual characteristics that distinguish successful researchers from others? If so, what are these characteristics? Which of these characteristics do you have?

How satisfied are you so far with your academic experiences in the Dept. of Botany? (1=completely dissatisfied, 5=completely satisfied) \_\_\_\_\_

How comfortable have you been with your experiences in the Dept. of Botany? (1=totally uncomfortable, 5=very comfortable) \_\_\_\_\_

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