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Article

Enhancing Diversity in Science: Is Teaching Science Process Skills the Answer?

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The Biology Fellows Program at the University of Washington aims to enhance diversity in science by helping students succeed in the rigorous introductory biology classes and motivating them to engage in undergraduate research. The composite Scholastic Achievement Test scores and high school grade point averages of the Biology Fellows are comparable to those of students who are not in the program; however, they earn, on average, higher grades in introductory biology classes than non-Biology Fellows. Underrepresented minorities and disadvantaged students in the program also earn higher grades in the introductory biology classes than do their non-Biology Fellows counterparts. Analysis of the performance of Biology Fellows shows that the program assists students who are not proficient in certain science process skills and that students who lack these skills are at risk for failing introductory biology. This evaluation provides insight for designing programs that aim to enhance the performance of beginning students of biology, particularly for underrepresented minorities, who want to obtain a life science degree.

INTRODUCTION

Despite many educational initiatives that have promoted the recruitment, fostering, and retention of women and underrepresented minorities (URMs) in Science and Engineering (SE) disciplines in the United States, these groups are poorly represented in these professions. Recent studies by the National Science Foundation (NSF) report that URMs lag far behind white and Asian students in the total number of science degrees earned (NSF, 2004). Equally alarming is that African Americans, Native Americans, and Hispanics together comprise only 5.8% of all employed persons with doctorates in SE disciplines (NSF, 2004). Moreover, women hold <18% of all tenured positions in SE fields even though they obtain 42% of all doctorates in these areas (NSF, 2004). For the past 30 years, efforts to improve educational outcomes for women and URMs in science have steadily increased, but the success of these efforts is not sufficient for future needs. Recent projections indicate that by 2050, racial/ethnic minorities will make up the majority of the U.S. college-age population (U.S. Census Bureau, 2000). Efforts to attract and retain URMs in SE disciplines must increase in order to provide adequate numbers of role models for this rapidly growing and diverse population of students.

URMs have numerous challenges to overcome while trying to compete in a rigorous college environment. Compared with whites and Asians, far fewer URMs enter college, and those who do are often economically disadvantaged and academically underprepared, coming from high schools that have not been as demanding as those attended by majority students (Cota-Robles and Gordan, 1999; Gandara and Maxwell-Jolly, 1999). As a result, many URMs exit science relatively early in their academic years. Only 27% of URMs and 46% of majority students who intend to major in an SE field go on to obtain an SE degree (Huang *et al.*, 2000; NSF, 2004). There are several reasons why they leave, including pedagogical practices that leave them uninspired (Seymour and Hewitt, 1997; Handelsman *et al.*, 2004). Unfortunately, many who switch or leave science majors have academic abilities equal to or more advanced than those who stay (Seymour and Hewitt, 1997). For others, the challenging and competitive nature of introductory science courses accounts for their early departure from SE majors.

For women, the leak in the pipeline occurs relatively late; although women earn more SE bachelor degrees than men and up to as many as 50% of doctorates in some SE fields, they are still less likely to pursue academic careers as re-

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search scientists (Huang *et al.,* 2000; NSF, 2004). An unfavorable environment mixed with a lack of encouragement, confidence, and role models have all been cited as factors that contribute to the departure of women from science (Widnall, 1988; Seymour, 1995; Handelsman *et al.,* 2005).

Escalating concerns about the lack of diversity in SE professions prompted the establishment of numerous programs that have developed successful strategies to help URMs and women overcome the barriers that prevent them from obtaining science degrees and advancing into faculty positions. Although some successful programs, such as the Minority Access to Research Careers program and the Meyerhoff Scholarship Program at the University of Maryland Baltimore County, use a very selective process to admit and support only high-achieving URMs, others aim to retain them (Jonides, 1995; Gandara and Maxwell-Jolly, 1999). For example, the Biology Undergraduate Scholars Program (BUSP) at the University of California (UC) at Davis, and the Biology Scholars Program (BSP) at UC Berkeley, identify all incoming URMs and offer them supplementary instruction for introductory science courses, direct access to paid research opportunities, and academic advising (Matsui *et al.,* 2003; Barlow and Villarejo, 2004). BUSP and BSP also provide students with a social network through program seminars, workshops, and social events. Thus, these programs develop all URMs by targeting them early and helping them to overcome academic, financial, and social barriers that often impede their path into science.

In an effort to help increase diversity in the sciences at the University of Washington (UW), and with support from the Howard Hughes Medical Institute, we established the Biology Fellows Program (BFP) in 2003. The BFP is based on the successful BUSP and BSP models that aim to develop students who are not prepared for the rigorous science majors. The overall goals of the BFP are to 1) create a sense of community for students as they adjust to a large campus, 2) excite students about careers in science and medicine, 3) assist students in finding a research experience as early as possible, and 4) help students complete the rigorous introductory biology series with competitive grades.

State regulations in California and Washington prohibit undergraduate institutions from using race, sex, ethnicity, color, or national origin as factors for admittance to college or special programs, such as the BFP. Therefore, diversity programs in these states have had to use a variety of strategies to recruit URMs. Concurrent with admission to the UW, the Educational Opportunity Program (EOP) admits URMs, economically disadvantaged students, and students whose parents do not have 4-year college degrees. We specifically recruit EOP students through networking with other campus programs and mailings to incoming freshman. The BFP supports up to 50 students each year.

At the UW, the entry-level courses in biology consist of a three-quarter sequence (Biology 180, 200, 220) that is required for most of the life science–related majors on campus. A review of 1581 EOP and 915 URM students during 2001–2003 showed, on average, 38% of URMs and 43% of EOP students entering Biology 180 received a grade below 2.0 or withdrew before completing the course. Fortunately, the biology curriculum at the UW is structured so that most students do not take introductory biology until their sophomore year, providing us with an opportunity to help prepare BFs before their first biology course. A unique feature of the BFP is that the program aims to teach students science process skills that we believe are needed for success in the introductory biology courses. We hope to better prepare students by teaching them science process skills before their immersion in biological content. To enhance BFs' success, we also provide optional supplementary instruction for all three introductory biology courses.

We evaluated the BFP to determine whether the program has had a positive impact on its participants. Here we present the quantitative analysis of the BFs' performance in the introductory biology classes and their proficiency gains in science process skills while in the program. In addition, we examined their engagement in undergraduate research and other factors that may predict their success in the introductory biology classes. We also discuss the implications of teaching students skills before immersing them in scientific content.

MATERIALS AND METHODS

BFP Participants

The BFP recruits freshmen, particularly targeting URMs and EOP students, who indicate to the UW admissions office that they intend to major in one of the following fields: biochemistry, bioengineering, biology, microbiology, neurobiology, zoology, or pre-health sciences. One requirement for participation in the BFP is that students may not take Biology 180 before or concurrently with the first quarter of the BFP class. However, students may take chemistry and math while enrolled in the BFP classes and often do, because these courses are prerequisites for Biology 180.

We define under-represented minorities as those who self-identify as African American, Hispanic (Chicanos and Latinos), Native American, or Pacific Islander. During the 2003–2005 academic years, three cohorts (n = 128) have completed the program. We used all three cohorts for our demographic analyses.

To gauge our success in recruiting women, URM, and EOP students, we compared the demographics of BFP students with those of the entire population of freshmen who enrolled between 2000 and 2004 who indicated they were interested in the above listed majors.

BFP Activities

The BFP is a two-quarter program that starts in the Winter quarter and meets once a week for 1.5 h. Although some BFs take Biology 180 during the second quarter of the BFP, the majority wait to start the introductory biology series until after they complete the program. All BFs are also strongly encouraged to participate in supplementary instruction sessions while taking the Introductory Biology courses. These sessions typically meet for 1 h each week and are run by peer tutors. This instruction is offered to both BFs and non-BFs; approximately half of the BFs take advantage of this opportunity.

In the BFP, we teach science process skills such as graphing, data analysis, experimental design, scientific writing, and science communication (Table 1). These skills are taught using a scaffolding approach that progressively challenges students to master these skills, while weaving them together through individual homework assignments and small group work in class. Students receive short lectures providing biological content and are given small group activities that allow them to collaboratively solve problems. Students are first taught basic experimental design, how graphs and tables are used to present data, and the different components of a primary journal article. This knowledge is reinforced with repeated assignments that require students to apply this information to new situations. Later, students are given more advanced assignments

Table 1. Science process skills taught in the BFP and methods of assessment

Science process skills	Topics covered	Assessment tools
Graphing	Understand graph types	Rubric, three writing assignments
	Make and interpret graphs	Pre- and posttests
	Convert graphs to text	TIPS
Data analysis	Interpret data tables	Rubric, two writing assignments
	Understand basic statistics	Summative test
	Infer conclusions from data	TIPS
Experimental design	Formulate hypotheses	Rubric, three writing assignments
	Identify variables	Pre- and posttests
	Control for variables	TIPS
	Know elements of experimental design	
Scientific writing and communication	Produce outlines	Rubric, six writing assignments
	Understand the elements of logical arguments	Graded summaries of journal articles
	Identify elements of a primary article	Evaluation of oral presentations
	Know types of scientific literature	Formative evaluation of poster schematics
	Draw basic schematics in biology	Summative test
	Give oral and poster presentations	

where they must synthesize these skills by using background scientific information and related data sets to present results, draw conclusions, and make predictions. For example, under instructor supervision, students work in pairs to graph raw data and to answer questions related to a scientific study. Students are then given individual homework assignments where they must write up their work in the form of a primary journal article. As the course progresses, students are given more challenging assignments based on new biological techniques and content presented to them. All assignments require students to use science process skills that are taught in the BFP.

The BFP also aims to create a small-campus atmosphere for BFs within a large university. Early in the program, students are required to complete several cooperative learning activities. For example, the "Science in the News" class requires teams of four or five students to work together to present a current science topic to the class. Throughout the program, BFs are given numerous opportunities to work in small groups so that they develop socially as a cohort. Another program requirement is that all students must attend an annual undergraduate symposium where they work in teams to present the BFP to other undergraduates on campus. BFs are also presented with information about other UW campus programs and opportunities for undergraduate research so that they may connect with other students and faculty on campus.

Analysis of Grades in the Introductory Biology Series

To assess the BFs' performance in the introductory biology series, we compared their grades with those achieved by the population of non-BFs who took the courses in the same time frame. For our analysis of Biology 180, grades were extracted from the UW student database for all students taking the course between Winter 2003 and Summer 2005. For analysis of performance in the series overall, grades were extracted for all students who completed Biology 220 between Winter 2003 and Summer 2005. Grades for the previous courses in the series (180, 200) were analyzed for this group of students. In cases where students had repeated a course two or more times for a numerical grade, the average of the first two recorded grades was used in the analysis, as per UW policy.

We examined the grades of 50 BFs who have completed Biology 180. Due to the fact that many students from the 2005 BFP cohort have not yet started the introductory biology series, this analysis only includes BFs from the 2003 and 2004 cohorts (Table 2). We further analyzed a subset of these BFs (33 students) who have completed the entire series. To investigate the potential for selection bias in the population of BFs, we also extracted several other variables for comparison: gender, ethnicity, EOP status, high school grade point average (GPA), and Scholastic Achievement Test (SAT) scores. *t* tests were performed on various dependent variables (high school GPA, SAT scores, Biology 180/series grades) using participation in the BFP as the independent variable.

Evaluation of Science Process Skills

BFs were tested as to whether they gained proficiency in the areas of interpreting graphs, experimental design, and data analysis over the course of the program. The following instruments were administered to the students in a pre- and posttest manner, with students completing the tests at the beginning and the end of the BFP, approximately 22 wk later (these materials can be downloaded from our Web site at http://depts.washington.edu/biology/hhmi/CBE). Except where noted in the text, only the 2005 cohort was used to assess science process skill proficiency.

Test of Integrated Process Skills (TIPS). TIPS was developed first by Dillashaw and Okey (1980); a second companion version of the test was developed in 1985 (Burns *et al.*, 1985). The test consists of 36 multiple-choice questions spread among five subscales: identifying variables, operational definitions, identifying testable hypotheses, data and graph interpretation, and experimental design. Students were given the two versions of the test in a cross-over design; that is, half of the students received version 1 as a pretest and version 2 as a posttest, and the other half received version 2 as pretest and version 1 as posttest. Within either the pre- or posttest, there were no significant differences between the mean scores for the two versions of the test. Not all students were able to complete the TIPS in the time allotted, so we recorded the percent of questions answered correctly out of those attempted. The average numbers of questions answered on the pretest and posttest were 33.9 and 35.1,

Table 2. Gender, race/ethnicity, and EOP status of BFs and non-BFs used in the introductory biology courses grade analysis

	BFs (n = 50)	Non-BFs (n = 2887)
Women	35 (70%)	1641 (57%)
URM	11 (22%)	163 (6%)
EOP	21 (42%)	520 (18%)

respectively. Students from the 2004 cohort took the TIPS at the end of their time in the BFP (i.e., posttest only), whereas students from the 2005 cohort took the TIPS at both the beginning and end of the program (i.e., pre- and posttest). For students who completed both pre- and posttests (n = 47), the median pretest score was 92% correct. Students scoring at the median and above (n = 25) and students scoring below the median (n = 22) were analyzed separately for pre- and posttest differences by paired *t* test.

We also wanted to determine whether the TIPS had any predictive value toward performance in the introductory biology series. To examine this possibility, we performed linear regression using TIPS posttest scores as the independent variable and the Biology 180 grade as the dependent variable for students from both the 2004 and 2005 cohorts who had completed both (n = 46).

Experimental Design Quiz. We designed this instrument to test students' abilities to generate a hypothesis-driven experiment after being given an imaginary scenario. Answers were open ended and were graded using a rubric that awarded between 0 and 3 points in each of four subject areas: the hypothesis being tested, the experiment being proposed, the understanding of variables involved, and the structure/flow of the response. Thus, each student could receive a maximum of 12 points. Students were given identical pre- and posttests at the beginning and end of the program. To prevent potential bias in grading, pre- and posttests were graded in random order by a grader who was blind to whether they were looking at the pre- or posttest for a given student. For students who completed both pre- and posttests (n = 41), the median pretest score was 6. Students scoring at the median and above (n = 17), and students scoring below the median (n = 24) were analyzed separately for pre- and posttest differences by paired *t* test.

Graphing Quiz. We designed this instrument to test students' understanding of basic graphing concepts, as well as their ability to read/interpret several different types of graphs. The quiz consisted of 12 questions, mixed between multiple choice and short answer, each worth one point, for a maximum of 12 points (half-points were possible for certain answers). Students were given identical pre- and posttests at the beginning and end of the program. For students who completed both pre- and posttests (n = 33), the median pretest score was 9.5. Students scoring at the median and above (n = 15) and students scoring below the median (n = 18) were analyzed separately for pre- and posttest differences by paired *t* test.

Evaluation of Attitudes toward Science

We administered the Test of Science Related Attitudes (TOSRA) to assess students' attitudes toward science. The TOSRA was developed by Fraser and Butts (1982). The original test consists of 70 items; a subset of 34 questions was given to BFs, covering five of the seven subscales of the instrument: career interest in science, adoption of scientific attitudes, attitude to scientific inquiry, normality of scientists, and social implications of science. Items consist of positively or negatively worded statements that students then indicate their amount of agreement or disagreement with using a five-point Likert scale. This survey was given to BFs at both the beginning and end of the BFP. Results were analyzed by paired *t* test to determine whether there was a significant change between pre- and posttest scores.

For all statistical tests, $p < 0.05$ was taken to indicate significant differences between pre- and posttest scores.

RESULTS

Successful Recruitment of URMs and Disadvantaged Students

To attract students to the BFP, we send out postcards to a subset of incoming freshmen who indicate an interest in the life sciences during the UW admissions process. We also advertise at student-centered functions on campus and through networking with relevant departments and other on-campus programs, particularly programs serving URM and EOP students. Students are admitted to the program regardless of gender or ethnicity.

To determine if the recruitment methods of the BFP are successful at reaching incoming women and disadvantaged students who are interested in science, we compared the demographics of BFs with non-BFs over a 5-yr period (Figure 1). Of the 128 students who have participated in the BFP since 2003, 75% were women, 42% were EOP, and 29% were URMs. During 2000–2004, the composition of incoming UW freshmen who indicated on their admissions application their intent to major in the life sciences was 64% women, 18% EOP, and 9% URMs. Thus the BFP recruits a large percentage of the total number of women, EOP, and URM students who are interested in life science majors.

Academic Background of Biology Fellows

To evaluate the academic qualifications of students recruited to the BFP, we compared the SAT scores and overall high school GPAs of BFs with those of non-BFs (Table 3); this also allows us to address the impact that SAT scores and high school GPAs may have on students' grades in the introductory biology courses.

We found that BFs and non-BFs had statistically similar mean composite SAT scores and mean overall high school GPAs. However, BFs had slightly higher mean verbal SAT scores than non-BFs (603 vs. 575, respectively; $p < 0.05$), but statistically similar mean math SAT scores.

Because non-EOP students perform better on average than EOP students in Biology 180, we compared SAT scores and high school GPAs of BF and non-BF students within these two groups. Analysis of EOP students shows that BFs had significantly higher SAT verbal scores than non-BFs (563

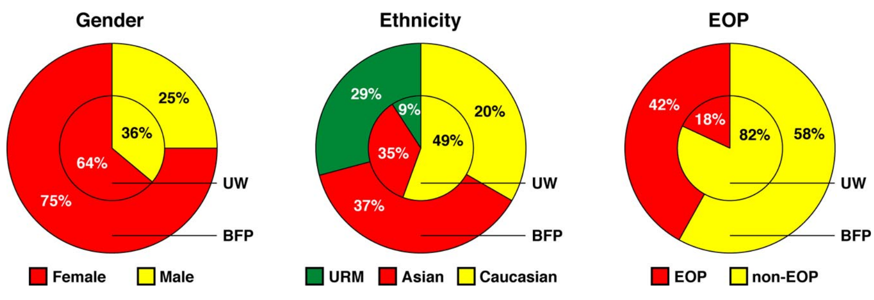

Figure 1. Demographics of BFs and recruiting population. Inner pie charts (labeled UW) represent breakdown of incoming UW freshmen between 2000 and 2004 who indicated on their application an interest in majoring in one of several life science–related majors (see text for complete list) by gender, ethnicity, and EOP enrollment. Outer pie charts represent the same categorical breakdown for BFs from 2003 to 2005.

Table 3. Mean ± SD high school (HS) GPA, composite (C) SAT, verbal (V) SAT, and math (M) SAT scores of BFs and non-BFs

	BFs			Non-BFs		
	All	EOP	Non-EOP	All	EOP	Non-EOP
HS GPA	3.78 ± 0.23 (45)	3.74 ± 0.22 (19)[a]	3.8 ± 0.24 (26)	3.75 ± 0.24 (2348)	3.66 ± 0.29 (453)	3.77 ± 0.22 (1895)
C SAT	1228 ± 176 (48)	1146 ± 171 (20)	1287 ± 156 (28)[b]	1199 ± 152 (2566)	1097 ± 152 (487)	1223 ± 142 (2079)
V SAT	603 ± 110 (48)[d]	563 ± 93 (20)[c]	633 ± 113 (28)[b]	575 ± 96 (2566)	518 ± 91 (487)	589 ± 92 (2079)
M SAT	624 ± 84 (48)	583 ± 88 (20)	654 ± 69 (28)	624 ± 81 (2566)	579 ± 84 (487)	634 ± 77 (2079)

[a] Sample size is given in parentheses.
[b] Statistically significant compared with non-EOP non-BFs, $p < 0.05$.
[c] Statistically significant compared with EOP non-BFs, $p < 0.05$.
[d] Statistically significant compared with non-BFs, $p < 0.05$.

vs. 518, respectively; $p < 0.05$), but had SAT math scores and high school GPAs that were similar to their non-BF counterparts. Among non-EOP students, BFs had significantly higher SAT verbal scores than non-BFs (633 vs. 589, respectively; $p < 0.05$), but had similar SAT math scores and high school GPAs. Thus, BFs have somewhat higher verbal SAT scores than non-BFs, regardless of EOP status.

Biology Fellows Succeed in the Introductory Biology Courses

Although BFs and non-BFs have statistically similar composite SAT and overall high school GPAs, BFs outperform non-BFs in Biology 180 (Table 4). The median GPA for BFs in Biology 180 is 3.3, compared with 2.7 for non-BFs. URMs in the BFP have a median GPA of 3.3 compared with 2.4 for URMs who do not participate in the program. Moreover, women and EOP students in the BFP perform better than their non-BF counterparts. Therefore, participation in the BFP correlates with high performance in the Biology 180 class.

Given that BFs have somewhat higher SAT verbal scores than non-BFs who took Biology 180, we attempted to adjust for this statistically by performing an analysis of covariance (ANCOVA). A one-way ANCOVA was performed with BFP participation as the independent variable, Biology 180 grade as the dependent variable, and SAT verbal score as the covariate. SAT verbal meets the requirements of a covariate: it is a reliable measure (within individuals), it is linearly related to the dependent variable ($r = 0.52$), and the slope of this regression is homogeneous across the groups of the independent variable. After adjusting for the effect of SAT verbal scores on Biology 180 grades, participation in the BFP still had a significant effect on Biology 180 grades ($p < 0.05$). After statistical adjustment, the mean Biology 180 grade for BFs was 2.89, compared with 2.61 for non-BFs.

BFs also performed better than non-BFs in the subsequent two classes of the introductory biology series, with overall median GPAs of 3.3 and 2.9, respectively (Table 5). The BFP URMs, women, and EOP students maintain their high performance compared with students who do not participate in the program.

A Correlation between Science Process Skills and Biology 180 Grades

We hypothesized that some students may be better prepared to apply certain types of science process skills in biology and that this may contribute to their success or failure in introductory biology courses. To examine this, we measured the abilities of BFs in certain skill areas using the TIPS and performed linear regression between scores on TIPS and performance in Biology 180. We found a statistically significant relationship between Biology 180 grades and scores on TIPS ($p < 0.001$; $r = 0.75$; Figure 2). Variation in TIPS scores accounts for 55% of variance in Biology 180 grades. Therefore, the lack of certain science process skills may be an important determinant of those who are at the greatest risk for failing introductory biology.

Table 4. A comparison of median and mean grades of BFs and non-BFs in Biology 180

	All students	URMs	EOP	Non-EOP	Women
BFs					
Median	3.3	3.3	2.7	3.4	3.2
Mean ± SD[a]	3.0 ± 0.9 (50)[b]	3.0 ± 0.8 (11)[b]	2.6 ± 1.1 (21)[b]	3.3 ± 0.6 (29)[b]	2.9 ± 1.0 (35)
Non-BFs					
Median	2.7	2.4	2.2	2.9	2.7
Mean ± SD[a]	2.6 ± 1.0 (2887)	2.3 ± 1.0 (163)	2.1 ± 1.0 (523)	2.7 ± 0.9 (2364)	2.6 ± 1.0 (1641)

[a] Sample size is given in parentheses.
[b] Statistically significant compared with non-BFs, $p < 0.05$.

Table 5. A comparison of median and mean grades of BFs and non-BFs in the introductory biology series (Biology 180, 200, and 220)

	All Students	URMs	EOP	Non-EOP	Women
BFs					
Median	3.3	3.2	3.0	3.5	3.1
Mean ± SD[a]	3.2 ± 0.58 (33)[b]	3.2 ± 0.43 (7)	3.0 ± 0.72 (14)[b]	3.3 ± 0.45 (19)[b]	3.1 ± 0.6 (25)
Non-BFs					
Median	2.9	2.8	2.6	3.0	2.9
Mean ± SD[a]	2.9 ± 0.61 (1392)	2.7 ± 0.63 (58)	2.6 ± 0.61 (246)	2.9 ± 0.60 (1146)	2.9 ± 0.6 (787)

[a] Sample size is given in parentheses.
[b] Statistically significant compared with non-BFs, $p < 0.05$.

Students Show Gains in Science Process Skills after BFP

Because UW introductory biology courses often use short-essay-answer exams that require students to read graphs, analyze data, or put forth basic experimental designs, we wanted to measure student gains in these skills while in the BFP. We found that, on average, BFs performed better on experimental design and graphing posttests than on pretests (Figure 3). To assess which students made the most progress in these areas, we separately analyzed students who scored above and below the median on pretests. Students who scored above the median on the pretests showed no gains on the posttests. However, students who scored below the median on the pretests showed statistically significant increases on the TIPS, experimental design, and graphing posttests, with average gains of 10, 65, and 20%, respectively (Figure 3). Thus, the BFP imparts basic experimental design and graphing skills to those students who lack these skills coming into the program.

Biology Fellows Have Positive Attitudes toward Science

The BFP recruits students who are motivated to major in a life science degree, and a main goal of the program is to foster BFs' positive attitudes toward learning science during their freshman year. To determine whether the BFP imparts some additional motivation to succeed, we measured the attitudes of BFs with the TOSRA. Of the five subscales we measured, only students' attitudes measured by the subscale "normality of scientists" showed a significant change, becoming 4% more positive. Students showed no gains in the other areas measured, but all scores were relatively high for both the pre- and posttests. BFs have relatively positive attitudes toward science coming into the program and maintain their enthusiasm throughout the program.

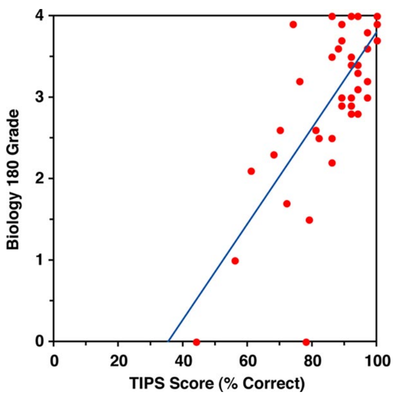

Figure 2. Relationship between TIPS scores (post-BFP) and Biology 180 grades.

Biology Fellows Form a Community of Science Scholars

To determine if the BFP creates a social network among participants, we used BFP yearly surveys and course evaluations to assess BFs' views regarding their peers and the general atmosphere of the program. Of the 67 students who responded to the most recent survey, 57% indicated that they occasionally see other BFs in class or on campus; another 33% report having close friendships, engaging in social activities, or participating in study groups with other BFs. Qualitative analysis of course evaluations and open-ended survey questions also show that BFs benefit from the two-quarter, small-class environment. Typical remarks that reflect the social community established by participation in the BFP include the following:

"This program makes a large university seem small and manageable. It boosts our confidence that we can meet our goals."

"I strongly believe that this Howard Hughes experience has made connections between people that will be mutually beneficial later on in the science world and in our lives."

"The UW campus is large and the classes even larger. Before the Hughes program I felt disconnected and relied on second-hand rumors for information regarding my academic career. I cannot stress enough what a difference the Hughes program has made."

BFP students form a community of scholars by participating in undergraduate research. In a survey of the 2003 and 2004 cohorts, 73% of BFs reported that they had engaged in undergraduate research. This is compared with 53% of seniors majoring in biology at the UW who indicated in an exit survey that they had participated in undergraduate research by the end of their senior year. Many BFs began their research during their freshman and sophomore years, and

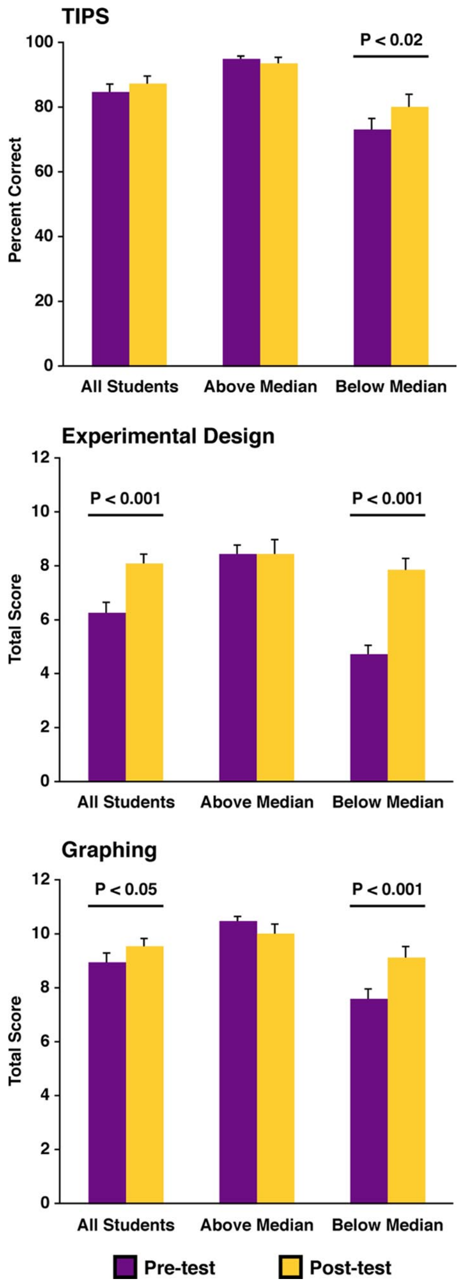

Figure 3. Results of in-class assessments of TIPS (top), experimental design (middle), and graphing (bottom). Purple bars indicate pretest means and SEM, gold bars indicate posttest means and SEM. Above/Below median indicates groups of students whose pretest scores were above or below the median, respectively. *p* values indicate significant differences between pre- and posttest values, as determined by paired *t* test.

57% of students in the program received funding for their research experience. In response to an open-ended question asking BFs if the program had helped them to find a research experience, over half of the students indicated it had. The following are typical responses:

"Yes, the outline for writing e-mails to professors and the information on where to find research positions was great. I used your steps and was able to find a research position in a couple of weeks."

"Yes. The instructor gave us the Web sites and guided us through the process of obtaining a research position. It was very helpful because all of the information given to us was new to me."

Thus, the BFP does create a personalized environment for BFs and provides them with useful information to connect them with other undergraduates and opportunities on campus.

DISCUSSION

Despite our inability to exclusively select URM and EOP participants for the BFP, we have nonetheless successfully recruited a relatively large number of these students to the program. This has allowed us to assist these groups of students who tend to do poorly in introductory biology at the UW. The BFP functions as an important part of a UW network of diversity programs that aim to help URM and EOP students in all introductory science courses.

An important goal of the BFP is to help students maintain their enthusiasm for science because many switch out of science majors early in their undergraduate education. Reasons for leaving science differ between various groups. URMs cite factors such as a lack of preparation when entering college, difficult introductory science courses, and inappropriate reasons for entering science, such as the influence of others at school or home; however, the majority of white students who leave science indicate that they get "turned off to science" because of poor teaching and the fast pace of the material presented (Seymour and Hewitt, 1997). In our analysis, TOSRA scores show that BFs have generally positive attitudes toward science coming into the program and maintain those attitudes throughout their participation. Considering that numerous BFs engage in undergraduate research early on, it suggests they view themselves as competitive scholars, capable of obtaining a research experience even if they have not yet taken biology. This indicates that the program provides these students with an environment that helps them to build confidence and appreciate the value of doing science. Undergraduates who participate in research reap numerous benefits such as learning a topic in depth, thinking like a scientist, and gaining valuable skills (Kardash, 2000; Lopatto, 2003; Seymour *et al.*, 2004). Certainly the benefits that BFs gain from their undergraduate research experiences may impact their success in biology in many ways. Therefore, future studies will be aimed at better understanding how the BFP affects students' views about themselves in science. Long-term studies that assess graduation rates and overall UW GPAs of BFs will help us to address whether participation in the BFP has a lasting effect on students beyond their first few years in college.

BFs, on average, earn relatively high grades in the rigorous introductory biology courses at the UW. For reasons that are unknown, the majority of BFP applicants are women, so the BFP predominantly serves women. BF women earn higher grades in all three of the introductory biology courses than do women who do not participate in the program.

Therefore, the BFP assists many women to continue their pursuit of earning life science degrees. Most importantly, the BFP helps EOP and URM students to earn, on average, higher grades in introductory biology than those students who do not participate in the program. In doing so, the BFP attenuates a major barrier that historically led many students within these groups to exit science.

In our analysis, we found that BFs and non-BFs have statistically equivalent overall high school GPAs and total SAT scores, but we were surprised to find that BFs have slightly higher verbal SAT scores than non-BFs. These data suggest a potential recruitment bias in BFP students and led us to consider this as a factor impacting their success in the introductory biology courses. To address this, we used ANCOVA to statistically adjust for the observed difference in SAT verbal scores and found that participation in the BFP was still a significant factor in determining Biology 180 grades. In other words, the success of BFs in Biology 180 cannot be explained entirely by their higher SAT verbal scores. Another way of looking at SAT scores is from the viewpoint of recruiting—is it a coincidence that the BFP tends to recruit students with higher verbal SAT scores? Perhaps high verbal SAT scores correlate with particular social characteristics that are indicative of the types of students who might seek out or who are attracted to programs such as the BFP. We are interested in further examining the reasons why we inadvertently recruit students with this attribute.

What aspects of the BFP contribute to the success of students in the introductory biology courses? The most likely answer is that all features of the program contribute at some level. Review of successful diversity programs shows that these programs usually offer a subset of five main components: mentoring, financial support, academic support, psychosocial support, and professional opportunities (Gandara and Maxwell-Jolly, 1999). Although the BFP incorporates many of these elements, one characteristic of the BFP that is unique is its focus on teaching science process skills. Thus far in the BFP, we have observed a robust relationship between science process skills (as measured by TIPS) and Biology 180 grades. A hypothesis extending from this observation is that increasing student abilities in such areas as reading graphs, analyzing data, and designing experiments may result in higher performance in the introductory biology courses. With the most recent cohort of BFs (2005), our data illustrate that a subset of students—namely, those who demonstrate low skills coming into the BFP—are showing learning gains in these skill areas. If our hypothesis is true, when students in this cohort finish taking Biology 180 we would expect to find, at least for the students who showed skill gains in the BFP, that students' posttest scores on the various skills assessments would be better predictors of Biology 180 grades than their pretest scores.

Considering the overall achievements of the BFP, we will continue to direct our efforts at identifying the factors that contribute to the success of BFs in the introductory biology classes. We believe that teaching students basic science process skills may play an important role in how students perform in introductory biology. Assessing what kinds of science process skills incoming freshmen lack and how they best learn them will help us to refine our strategies for effectively teaching them. With tailored instructional tools, we may be able to more efficiently prepare disadvantaged students to succeed in introductory science courses and perhaps even close the gap between them and the majority. Such a knowledge base will enable us to better serve all students and hopefully increase the pool of high-achieving URMs in biology.

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REFERENCES

Barlow, A., and Villarejo, M. (2004). Making a difference for minorities: evaluation of an educational enrichment program. J. Res. Sci. Teach. *41*, 861–881.

Burns, J., Okey, J., and Wise, K. (1985). Development of an integrated process skill test: TIPS II. J. Res. Sci. Teach. *22*, 169–177.

Cota-Robles, E. H., and Gordan, E. W. (1999). Reaching the Top: A Report of the National Task Force on Minority High Achievement, New York: The College Board.

Dillashaw, F., and Okey, J. (1980). Test of the integrated science process skills for secondary science students. Sci. Educ. *64*, 601–608.

Fraser, B. J., and Butts, W. L. (1982). Relationship between levels of perceived classroom individualization and science-related attitudes. J. Res. Sci. Teach. *19*, 143–154.

Gandara, P., and Maxwell-Jolly, J. (1999). Priming the Pump: Strategies for Increasing Underrepresented Minority Graduates, New York: The College Board.

Handelsman, J., *et al.* (2004). Scientific teaching. Science *304*, 521–522.

Handelsman, J., *et al.* (2005). More women in science. Science *309*, 1190–1191.

Huang, G., Taddese, N., and Walter, E. (2000). Entry and Persistence of Women and Minorities in College Science and Engineering Education, Washington, DC: U.S. Department of Education, National Center for Education Statistics. http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2000601 (accessed 1 October 2005).

Jonides, J. (1995). Evaluation and Dissemination of an Undergraduate Program to Improve Retention of At-Risk Students, Washington, DC: Fund for the Improvement of Postsecondary Education.

Kardash, C. M. (2000). Evaluation of an undergraduate research experience: perceptions of undergraduate interns and their faculty mentors. J. Ed. Psych. *92*, 191–201.

Lopatto, D. (2003). The essential features of undergraduate research. Council on Undergraduate Research Quarterly *23*, 139–142.

Matsui, J., Liu, R., and Kane, C. (2003). Evaluating a science diversity program at UC Berkeley: more questions than answers. Cell Biol. Educ. *2*, 117–121.

National Science Foundation, Division of Science Resources Statistics (2004). Women, Minorities, and Persons with Disabilities in Science and Engineering, Washington, DC. NSF 04-317.

Seymour, E. (1995). The loss of women from science, mathematics, and engineering undergraduate majors: an explanatory account. Sci. Educ. *79*, 437–473.

Seymour, E., and Hewitt, N. (1997). Talking about Leaving: Why Undergraduates Leave the Sciences, Boulder, CO: Westview Press.

Seymour, E., Hunter A., Laursen, S., and Deantoni, T. (2004). Establishing the benefits of research experiences for undergraduates in the sciences: first findings from a three-year study. Sci. Ed. *88,* 493–534.

U.S. Census Bureau (2000). Projections of the total resident population by 5-year age groups, race, and Hispanic origin with special age categories: Middle series, 2050 to 2070, NP-T4-G. January 2000. http://www.census.gov/population/projections/nation/summary/np-t4-g.txt (accessed 10 September, 2005).

Widnall, S. (1988). AAAS presidential lecture: voices from the pipeline. Science *24*, 1740–1745.