V. QUANTITATIVE FINDINGS FOR STUDENTS

Participants' professional enhancement and consequent development of new or revised courses means little if students do not take the courses or if the changes do not result in improved student learning. In this chapter, we examine how many students took participants' new or revised courses, and participants' estimation of students' performance in such courses.

Numbers of Students in Participants' New and/or Revised Courses

> Desired outcome: Institutions offer SMET courses/labs for undergraduates that are state-of-the-art in their content and technology, incorporate best practices in their pedagogy, are accessible to all students, and are relevant to the real world.

Telephone survey respondents who had made major revisions to existing courses or had developed new courses reported that, on average, 71 students completed such courses each year,[1] and respondents who had made at most moderate revisions to existing courses reported that, on average, 81 students completed their courses each year.

Respondents' estimates of the characteristics of students completing the new or revised courses are shown in Exhibit V-1. According to survey respondents who developed new courses or made major or moderate revisions to existing courses, approximately 46% of their students were female and 25% were from underrepresented minority groups. This percentage of females is slightly lower than the percentage of females among all undergraduate students in the United States in 1996 (52%), but the percentage of students from underrepresented minority groups is approximately the same as the national percentage (22%). (National Science Board, 2000, Appendix Table 4-32.)

[1] Respondents were asked, "In all, approximately how many students have completed this course/these courses?" From the responses, we calculated yearly means.

Exhibit V-1. Gender, Race/Ethnicity, and Institutions of Students Affected by Changes

	New and/or Substantially Revised Courses (Percent)
Gender	
Male	54
Female	46
Race/Ethnicity	
Not underrepresented minority	75
Underrepresented minority	25
Institutional type	
Two-year colleges	29
Four-year colleges	28
Comprehensive universities	24
Doctoral institutions	19
HBCUs	4
Tribal colleges	<1

Source: SRI Participant Survey.

From these reports, conservative estimates of the numbers of students in UFE-affected courses are as follows:

By the end of 1999, approximately 1,850,000 students had completed courses that were developed or had undergone *major* revisions as a result of the 1991-1997 UFE workshops.[2] These included approximately:

- **857,000 females**
- **527,000 from underrepresented minority groups**
- **546,000 in 2-year colleges**
- **495,000 in 4-year colleges**
- **521,000 in comprehensive institutions**
- **288,000 in doctoral institutions.**

Approximately 965,000 additional students had completed courses that had undergone *moderate* revisions as a result of the 1991-1997 UFE workshops. These included approximately:

- **455,000 females**
- **232,000 from underrepresented minority groups**
- **279,000 in 2-year colleges**
- **287,000 in 4-year colleges**
- **147,000 in comprehensive institutions**
- **252,000 in doctoral institutions**.

[2] See Appendix E for calculations.

Impact of New and/or Revised Courses on Students

Desired outcome:

Undergraduate students, including those from underrepresented groups, gain proficiency in SMET, improve their attitudes toward SMET, and are prepared to apply SMET concepts to their lives.

Knowing that large numbers of students were in UFE participants' courses does not tell us *how* the changes that participants made in their courses affected students. Clearly, one of the participants' desired goals was that students improve their subject matter knowledge. But at least as important is that students acquire the skills and abilities they need in the modern world and workplace. Thus, in addition to knowledge of subject matter, our indicators of positive outcomes for students also included a positive change in students'

- ability to apply new knowledge
- problem-solving skills
- critical thinking skills
- ability to collaborate with others
- communication skills
- ability to use advanced technology
- understanding of the scientific method.

For each of these outcomes, we asked telephone survey respondents to compare the average level of knowledge and skills of students who completed the courses they had developed or modified as a result of participating in a UFE workshop with the knowledge and skills of students who completed similar courses they had taught previously. (If there was no valid basis for comparison, respondents were asked to so indicate.) According to faculty reports, students have benefited in a number of ways from the new or revised courses. Approximately four-fifths of respondents who developed new courses or made major or moderate revisions to existing courses reported that students who completed those courses had more in-depth knowledge of the subject area, better critical-thinking skills, better problem-solving skills, and better ability to apply new knowledge than students in similar courses the respondent had previously taught. From 17% to 20% of respondents rated their students' knowledge and skills along these dimensions as "*substantially* better."

Exhibit V-2 shows the associations of particular changes that participants made with particular student outcomes.[3,4] Every dimension of students' knowledge and/or performance was affected in some way by participants' changes. The larger the changes made by participants, the more likely they were to report improvements in students' outcomes. Respondents who made no changes or small changes were the most likely to report that there was no difference in their students' performance and the least likely to report that their students did substantially better. Conversely, participants who made major changes were the least likely to report that there was no difference and the most likely to report that their students did substantially better.

In terms of students' knowledge of subject matter, more than 80% of survey respondents who made major changes to content reported that their students did somewhat or substantially better after the changes. Forty-three percent of those who introduced new content and 34% of those who increased their focus on "big ideas" reported that their students did substantially better.

[3] The selection of the particular types of changes made by participants for Exhibit V-2 was made *a priori* on a theoretical basis, not on the basis of statistical significance.

[4] Participants who indicated that there was no valid basis for comparison (e.g., because they developed a course they had never taught before) are not represented in Exhibit V-2.

Exhibit V-2. Impact of Participants' Changes on Students' Knowledge and Skills*

Category of Students' Knowledge or Skills	Level of Participants' Changes in Courses	Percentage of Participants Reporting that Students' Performance** Was:		
		Worse or the Same	Some-what Better	Substan-tially Better
Knowledge of subject matter				
Participant introduced new content to courses ($p < .001$)	No or small changes	36	54	10
	Moderate changes	21	67	12
	Major changes	12	45	43
Participant increased focus on "big ideas" ($p < .001$)	No or small changes	29	60	11
	Moderate changes	24	60	16
	Major changes	16	50	34
Ability to apply knowledge				
Introduction of new content ($p < .001$)	No or small changes	26	64	11
	Moderate changes	22	60	17
	Major changes	13	54	33
Increased focus on "big ideas" ($p < .001$)	No or small changes	30	59	11
	Moderate changes	16	67	18
	Major changes	14	54	32
General changes in teaching methods ($p < .001$)	No or small changes	26	59	15
	Moderate changes	21	66	13
	Major changes	11	56	33
Problem-solving skills				
Increased focus on "big ideas" ($p < .001$)	No or small changes	32	57	11
	Moderate changes	18	66	16
	Major changes	15	58	27
Introduction of new lab techniques ($p < .001$)	No or small changes	32	56	12
	Moderate changes	23	66	11
	Major changes	16	58	25
Introduction of new technologies ($p < .001$)	No or small changes	29	57	14
	Moderate changes	23	64	13
	Major changes	16	60	24
General changes in teaching methods ($p < .001$)	No or small changes	30	58	13
	Moderate changes	20	69	11
	Major changes	14	56	30
Critical-thinking skills				
Increased focus on "big ideas" ($p < .001$)	No or small changes	31	59	10
	Moderate changes	19	65	16
	Major changes	12	54	34
Introduction of new lab techniques ($p < .001$)	No or small changes	30	56	14
	Moderate changes	18	66	16
	Major changes	9	60	31
Ability to collaborate with others				
Introduction of new lab techniques ($p < .001$)	No or small changes	36	45	19
	Moderate changes	31	49	20
	Major changes	17	39	43

Exhibit V-2. Impact of Participants' Changes on Students' Knowledge and Skills* (concluded)

Category of Students' Knowledge or Skills	Level of Participants' Changes in Courses	Percentage of Participants Reporting that Students' Performance** Was:		
		Worse or the Same	Some-what Better	Substan-tially Better
Ability to collaborate with others (continued)				
Introduction of new technologies ($p < .001$)	No or small changes	30	44	25
	Moderate changes	33	49	19
	Major changes	19	39	41
General changes in teaching methods ($p < .001$)	No or small changes	38	42	20
	Moderate changes	24	52	24
	Major changes	10	41	49
Communication skills				
Increased focus on "big ideas" ($p < .001$)	No or small changes	50	35	14
	Moderate changes	37	46	17
	Major changes	34	43	23
General changes in teaching methods ($p < .001$)	No or small changes	54	33	13
	Moderate changes	36	50	14
	Major changes	21	48	30
Ability to use advanced technology				
Introduction of new lab techniques ($p < .001$)	No or small changes	34	43	23
	Moderate changes	15	53	32
	Major changes	13	31	56
Introduction of new technologies ($p < .001$)	No or small changes	39	39	21
	Moderate changes	12	57	31
	Major changes	6	30	64
Understanding of the scientific method* **				
Introduction of new content ($p < .001$)	No or small changes	39	41	20
	Moderate changes	43	46	11
	Major changes	29	43	28
Increased focus on "big ideas" ($p < .001$)	No or small changes	48	40	11
	Moderate changes	33	52	15
	Major changes	29	41	31
Introduction of new lab techniques ($p < .001$)	No or small changes	47	40	13
	Moderate changes	41	44	15
	Major changes	27	46	26
General changes in teaching methods ($p < .001$)	No or small changes	43	46	11
	Moderate changes	43	42	15
	Major changes	25	40	35

*As reported by survey respondents.

**Students' performance after respondents made changes to their courses that they attributed the workshop, compared with the performance of students in similar courses respondents had taught before the workshop. Participants who indicated that there was no valid comparison group of students are not included.

***Does not include participants at mathematics w orkshops.

Participants who made some types of changes in their courses also reported that their students' skills and abilities improved in other dimensions. Approximately a third of respondents who made major changes by introducing new content, increasing focus on "big ideas," or generally changing teaching methods reported that their students' ability to apply new knowledge was improved substantially. From 24% to 30% of respondents who made major changes of these types or introduced new lab techniques or new technologies also reported a substantial improvement in their students' problem-solving skills.

Improvements in students' critical-thinking skills and communication skills were similarly associated with faculty's increased focus on "big ideas" and changes in their teaching methods. In addition, from 41% to 49% of respondents who made major changes in lab techniques, advanced technologies, or general teaching methods reported that their students' ability to collaborate was substantially improved. Not surprisingly, a majority of respondents who updated their lab techniques in major ways (56%) or introduced more advanced technology (64%) in their courses reported that their students' ability to use advanced technology was improved.

Lastly, students' understanding of the scientific method was improved by participants' introduction of new content, increased focus on "big ideas," introduction of new lab techniques, and general changes in teaching methods. Introduction of new technology into the classroom was not significantly associated with the percentage of participants reporting improvement in student performance in this category.

Respondents were asked to describe in their own words the changes in their students' performance. Typical answers were:

"My students are aware of concepts they weren't aware of, like evolution at a molecular level. They've become good at new technologies…. They now are able to see they can solve field problems using molecular techniques. They can ask academic questions they previously wouldn't have thought of. They are better prepared for the job market and grad school in molecular biology."

"The students are more interested in what they are doing. They are working together as a team and seem to be understanding and getting concepts that other students prior to changing the class could not understand."

"They do more in-depth thinking about the problem—understanding the solution and how it answers the question."

"They understand differential equations for what they mean, rather than what they look like. They also better understand subject matter from previously taught courses. [The changes I made] integrated their previous knowledge so they can better grasp concepts."

"My students' application of calculus to real-world problems became second nature to them."

"Students were able to learn new techniques and work with new instrumentation, which gives them a background that they can use in their future research."

"They're better prepared for technology they're likely to encounter in the professional world."

"They communicate and cooperate with each other better. They're more familiar with computers."

"The attendance is much better, and they do better on the communication aspect of statistics."

"[The changes I made] gave them the opportunity to develop projects that applied their learning. They had to report their products in writing and orally, which improved communication skills and overall skills."

Could faculty have overreported the extent of the impacts on their students? We cannot discount that possibility. We attempted to minimize positive exaggerations by separating questions about student performance from questions about changes faculty had made (and, because the interview was conducted by telephone, respondents could not go back to check what they had answered to previous questions). However, it is possible that faculty who have put substantial work into developing or revising courses may be more likely than others to believe that their work has paid off in terms of student performance. Assessing the validity of faculty's beliefs about student performance was not within the scope of this study.

Summary

We estimate that, by 1999, more than 1,850,000 students had completed courses that were developed or had undergone major revisions as a result of the UFE workshops held in 1991-1997. Approximately 965,000 additional students had completed courses that had undergone *moderate* revisions as a result of the workshops. Slightly fewer than half of these students were female, and approximately one-quarter were from underrepresented minority groups. About the same percentages of students (28%) were in 2-year, 4-year, and comprehensive institutions, and about 11% were in doctoral institutions.

Faculty reported that students in their revised or modified courses performed better along of number of dimensions than comparable students in traditional courses. In

addition to improvements in content knowledge, faculty cited improvements in students' abilities to solve problems, think critically, communicate, collaborate, use technology, and understand the scientific method. The greater the changes faculty made to their courses, the more likely they were to report substantial improvement in their students' performance. Because student performance was not observed or measured by third parties, the extent to which faculty may have overreported the improvements in their students' performance is not known.