Introduction

AFTER MANY YEARS DOING RESEARCH related to improving undergraduate science education, I became convinced that it was time for broad-based change. The evidence was overwhelming that new research-based methods were superior to the lecture instruction found in most college science classrooms. It was also clear to me that the faculties of science departments were mostly unaware of this superiority, even in the situations where active research on improving science education was taking place within their own departments. Although an enormous number of individual experiments had been designed to improve single courses, none had broadened their focus to the problem of bringing the most successful teaching methods to scale. I launched the Science Education Initiative (SEI) at the University of Colorado and the University of British Columbia as an attempt to determine whether it was possible to get entire science departments to adopt these better teaching methods.

This book tells the story of the initiative. The assumption behind the decision to publish it is not that many institutions will seek to replicate the whole experimental adventure. Rather, by seeing the thinking and effort that went into it, they can be more confident that the method has produced insights they can use. Other programs attempting to improve the quality of university-level science, math, or engineering instruction can benefit from this experience. Many of the SEI's lessons learned would be valuable in the design and implementation of any size program for improving undergraduate

Table 0.1. Features of the SEI programs

	University of Colorado	University of British Columbia
Total funding	$5.3 million	$10.8 million
Funding per department	$150,000–$860,000 (avg. $650,000)	$0.3 million–$1.8 million (avg. $1.4 million)
Total number of science education specialists	24	52
Transformed courses/credit hours per year	71/53,000	164/139,000
Number of faculty who changed teaching methods (ranging from 10–90 percent of departments)	102	180

Note: Funding per department was averaged over the six fully funded departments at CU and six departments at UBC, since the three-department undergraduate biology program was funded as a single department.

teaching. Even more broadly, the information and conclusions that emerged from this effort are relevant to efforts to bring about other forms of widespread change in university settings. The SEI and the effort to compile this book yield a uniquely valuable set of observations about the operations of academic departments, about how departments can best support change, and about the many ways change efforts can fail.

It is possible to sum up the major findings of the SEI in a few headlines. First, the initiative showed that *it is possible to achieve widespread change within departments.* As Table 0.1 illustrates, this was a substantial project that had a large impact. It altered the teaching of nearly 200,000 credit hours per year at these two institutions, changing how nearly 300 science faculty went about their work in 235 courses. Major portions of faculty (up to 90 percent in the most successful departments) adopted new teaching methods, and the level of transformation (in terms of both absolute numbers and percentages of undergraduate credit hours) was substantial. There is good evidence of the sustainability of these changes, at least as measured in the short term. However, there was wide variation across the departments as to the level of success, suggesting many general lessons about what helps and hinders such educational innovation.

The SEI made clear that *virtually all faculty want to teach well, and nearly all faculty can learn to use new teaching methods effectively, but the methods recommended by the SEI do involve a significant initial learning curve.*

There are, of course, substantial challenges to implementing many kinds of change in universities. The SEI revealed that *the largest barrier to faculty change is the formal incentive system.* Faculty see the institutional incentive system as penalizing any time taken away from research to improve teaching or make use of nontraditional teaching methods. When faculty members did embrace new teaching methods, it was usually because they valued the greater personal satisfaction they would experience with students' improved engagement and learning.

In the most successful departmental change efforts, certain key elements stood out. First, *a substantial competitive grant program for departments to improve undergraduate education was clearly effective.* Second, *there was great value in having science education specialists (SESs) with expertise both in their discipline and in teaching embedded in the departments to work with the faculty.*

Third, although each department's experience differed, *the primary determinant of departmental success was the overall quality of organization and management within the department.* Each department's particular culture played a crucial role in how it viewed and carried out educational change.

Finally, it became evident that *persistence and flexibility were essential, as some of the SEI's initial assumptions were wrong and many unexpected issues arose.* Many adjustments were needed based on what was learned over the course of the SEI. These changes resulted in substantial improvements.

A Guide to the Book

Chapter 1 begins with my vision of an optimized university: one that produces the best education possible in the most efficient manner within the current resource constraints. This is the ultimate goal toward which the SEI was striving. Chapter 2 presents the model of change incorporated in the SEI, the principles behind that model, and its specific components. This is based on theories of organizational change and the adoption of innovation as mapped onto the context of a science department at a large research

university, the necessary unit of change. It also incorporates my own experience at successfully transforming several courses by a specific process of backward design. Chapter 3 is a lengthy discussion of the SEI implementation. It explains how the SEI funded departments through a competitive grant process, and how departments then used the funds to support the process of changing how courses were designed and how faculty taught, assisted by SESs embedded in the departments. Changes in courses were informed by a three-pronged effort to define what students *should* be learning; to measure accurately what they *were* in fact learning; and to introduce more effective research-based instructional practices to improve that learning. Chapter 4 describes the role of SESs, whose somewhat novel position played a vital role in this innovation process. I discuss how they were hired and trained, how they typically functioned within departments, and where their subsequent career paths took them. Chapter 5 presents all that we accomplished in the SEI. Beyond the departmental-level statistics on how many courses and faculty were affected and what specific changes were made, the chapter discusses broader impacts on how these departments view and carry out educational change. Chapter 6 takes stock of the SEI's model, identifying which aspects of it worked well, which required modification, and which simply failed. In a university setting, the quality of learning hinges on faculty decisions about how to teach. This chapter offers my conclusions about what factors drive those decisions and how well the SEI was able to influence them. In the Coda, I draw together everything that I have learned from the SEI in order to advise faculty and administrators who desire to make large-scale improvements in science education at their institutions. In other words, as someone who began his work as a science educator decades ago, I share what I would have done then had I known what I know now.