What Was Achieved and What We Learned

THE SEI WAS fundamentally an experiment in institutional change and much was learned from that experiment. This chapter presents the rich set of data that was produced and all that the experience revealed. This ranges from detailed measurements of changes in teaching methods used in various courses to subtle observations of how departments function and oversee their courses, and how these differences impact the quality of teaching. Included in the results are discoveries of how institutional structures and values make it very difficult to collect some types of data, particularly instructor-independent measures of learning. In this chapter I show the substantial changes in teaching that were achieved, the contrasts in achievement across departments, and the differences that were responsible for these contrasts. This reveals a number of traditions that had inadvertently become established in individual departments and that negatively impact educational quality. The information in this chapter reveals the many opportunities for teaching improvement and the myriad issues that can interfere with educational improvement at this level, as well as many clever approaches developed by departments to make their SEI efforts successful.

As discussed in Chapter 3, the implementation of the SEI revealed unexpected challenges in collecting data. However, many types of data were collected on the impact of the SEI and how this varied across departments and institutions. This data include some results on student learning outcomes and evaluations, and extensive data on the adoption of new teaching methods, including the number of courses and faculty using these methods. There are also many observations about the relevant respective departmental organizations and functioning and how these impacted the success of SEI activities. I also present information on the changes in the departmental cultures at the different institutions. Lastly, I present some information on economic issues, including the impact of the SEI on instructional costs.

Student Learning Outcomes

In spite of the data collection difficulties, there were many examples where student learning outcomes were measured for individual courses and for particular learning activities, often with comparisons with outcomes from previous iterations of the respective course. Collection of these data were usually instigated and carried out by SESs, particularly those interested in pursuing careers in science education research. Many of these have been published or presented at conferences and are in the list of 120+ publications of the SEI at www.cwsei.ubc.ca/SEI_research. Some representative examples are listed in Table 5.1.

There are also a number of additional examples that have not been published. In nearly every case these examples showed that when research-based instruction was put in place in the SEI, it resulted in improved student learning. The few exceptions usually involved courses where there were very serious problems with the basic content and organization (see "Curriculum Issues" in Chapter 6). Those examples demonstrated that if a course is badly designed, the quality of pedagogy makes little difference. Generally, such a course was a large, apparently random, collection of topics joined together for ancient and unknown reasons and misaligned with student preparation.

Student Course Evaluation Results

The institutions collect student course evaluations in every course. These data were found to be of little value, both because of the general limitations of student evaluations and the fact that the questions on the student evaluation forms used at both UBC and CU were of questionable design.[1] As a result, the primary interest in looking at the student evaluations was to check if the transformed courses had lower or higher evaluations than their traditional counterparts. It is frequently claimed, though usually with little supporting data, that

Table 5.1. Published examples of SEI measurements of student outcomes

Title	Reference
Why peer discussion improves student performance on in-class concept questions	Smith et al., *Science* 323, no. 5910 (2009): 122–124
Using invention to change how students tackle problems	Taylor et al., *CBE—Life Sciences Education* 9, no. 4 (2010): 504–512
Learning and retention of quantum concepts with different teaching methods	Deslauriers and Wieman, *Physical Review Special Topics: Physical Education Research* 7 (2011): 010101
Improved learning in a large enrollment physics class	Deslauriers et al., *Science* 332, no. 6031 (2011): 862–864
The Colorado Learning Attitudes about Science Survey (CLASS) for use in biology	Semsar et al., *CBE—Life Sciences Education* 10, no. 3 (2011): 268–278
Successful curriculum development and evaluation of group work in an introductory mineralogy laboratory	Dohaney et al., *Journal of Geoscience Education* 60, no. 1 (2012): 21–33
Teaching methods comparison in a large calculus class	Code et al., *ZDM Mathematics Education* 46, no. 4 (2014): 589–601
Educational transformation in upper-division physics: the SEI model, outcomes, and lessons learned	Chasteen et al., *Physical Review Special Topics: Physical Education Research* 11 (2015): 020110
Teaching critical thinking	Holmes et al., *Proceedings of the National Academy of Sciences* 112, no. 36 (2015): 11199–11204
Transforming a fourth-year modern optics course using a deliberate practice framework	Jones et al., *Physical Review Special Topics: Physical Education Research* 11 (2015): 020108
Teaching students how to check their work while solving problems in genetics	McDonnell and Mullally, *Journal of College Science Teaching* 46, no. 1 (2016): 68–75

introducing active learning methods into a class will result in student course evaluations going down. This was a fear often heard from faculty.

Sampling of student evaluations for faculty at both institutions showed that a faculty member's student evaluations typically remained unchanged (within statistical uncertainties) from before to after SEI course transformations. This was true even though in most of those cases the teaching methods were dramatically changed and in many cases data showed substantial improvements in learning. As noted in Appendix 1, faculty received specific guidance on how to get student buy-in for research-based teaching methods. Without this guidance, the student evaluation results might have been different.

There were a few cases where there was a notable decrease in the evaluation score. To my knowledge, these all involved cases where a faculty member made a large number of changes in a course all at once without, in my judgment, adequate preparation. Students rated the instructor significantly lower than in previous years and commented that the course was disorganized and poorly prepared (a sentiment shared by the associated SESs). However, the evaluations then rebounded in the following year, when the courses were presumably better prepared.

In the one department (UBC EOAS) where there was the most widespread shift in teaching methods, the teaching evaluations across the entire department were compared after roughly half the courses were being taught in transformed fashion. From that data, it appeared that student evaluations of the faculty who had altered their teaching remained unchanged from the pre-SEI period, but the evaluations of the faculty who had not changed their teaching had gone down compared to their pre-SEI evaluations. This suggested that the students' standards were changing as a result of their exposure to research-based teaching methods. There is a fair amount of noise in this data, however, so this conclusion is not definitive.

One final caveat is that the comparison of student evaluation scores before and after SEI course transformations may be skewed by differences in class attendance. Typically, attendance is higher, often much higher, in the transformed courses than in the standard lecture courses. Hence, when student evaluations are filled out in class, the response rates are likely higher in transformed courses, which may shift the results due to a difference in selection bias of the responders. Presumably students who do attend a class that has low attendance see it more favorably than do the students who choose to not attend.

Adoption of Research-Based Instructional Practices

The cleanest and most extensive data we were able to collect were on the number of faculty who made changes in their teaching methods, and the nature of those changes. These data were provided by the regular SES reports, the annual department reports, and various faculty surveys and interviews carried out by SESs and SEI Central, and they reveal both the extent and type of changes that were implemented.

An analysis looking across the multiple sources of data shows that a substantial majority, although not all, of the changes in faculty teaching practices came about through working on SEI-supported course transformations with an SES. Almost none of the faculty adopted new teaching methods without an SES at least providing consultation or guidance in some form.

The comparison across departments as to the adoption of new teaching methods is highly informative. By combining the quantitative results given below with our extensive knowledge of the functioning of the departments and the different ways they ran their SEI efforts, we could see what factors encouraged the adoption of new methods, as well as identify a number of barriers.

CU SEI data. SEI Central at the University of Colorado conducted interviews with departmental SESs and SEI department directors in 2009, 2013, and 2014 to gather data on how courses and faculty had been impacted by the SEI. Using a structured spreadsheet, information was gathered on each course and each faculty member in the department, such as whether learning goals or clicker questions had been developed for that course, or whether a faculty member had participated in learning goal discussions or made substantial use of the SES. In the spring of 2010, a short survey was given to faculty in all the departments of CU participating in the SEI to document their level of interaction with the program and the impact they felt it had on their teaching.[2] Of the 162 faculty who were asked to participate, 114 responded. The survey responses are heavily skewed toward the faculty who were participating in SEI activities, and so we believe that few of the non-responders had made changes in their teaching. These faculty self-report data were checked with follow-up discussions with department directors and SESs, cross-checked with annual reports from each department, then collected and coded in a massive spreadsheet showing the detailed changes that were made in all the courses and in the teaching of all of the faculty who responded. Course or faculty "impact" was defined as the total number of changes catalogued in the spreadsheet for an individual course or faculty member in terms of learning goals, assessment, and instruction, where the latter two categories are broken down into subcategories to provide a more detailed picture of the changes.

UBC SEI data. The data on course and faculty impact were somewhat easier to collect at the University of British Columbia and relied less on self-reports, as the requirement for an annual report from each department, including details on each course transformation and the faculty involved, was established from the beginning. At UBC, the changes in courses and teaching made by faculty were more likely than at CU to be part of a systematic course transformation in which faculty worked with an SES, and hence were more likely to be documented in one of these reports, which were prepared by the SESs and SEI department directors. These reports did not capture changes in teaching that faculty members might carry out on their own, for example, in response to discussions or workshops run by an SES or inspired by previous work on an SEI course transformation. However, since there were more SESs at UBC than at CU, and they were thoroughly embedded in the departments and interacted routinely with many faculty, it is unlikely that there were many such course changes that the SESs did not have some part in, although we do know of a few. We took the data from the UBC annual reports, and in some cases supplementary reports on specific course transformations, and coded them in a similar fashion as done with the CU data, analyzing them in terms of the specific changes made in the course or in the style of instruction, and using this to create a second massive spreadsheet that classified the extent of changes in course and faculty teaching across all of the SEI departments.

Quantitative Summary of Changes in Teaching by Department

In Table 5.2 we show the impact in each department according to (1) the number and fraction of faculty in a department that made major or modest changes in their teaching methods, (2) the number of courses in which teaching changed substantially, and (3) the number of student credit hours (absolute and as fraction of total provided by department) being taught in a significantly improved manner.

The most common changes in instruction were (1) adoption of learning goals that define desired outcomes in operational terms of student competencies and attitudes; (2) incorporation of various in-class active learning methods such as peer instruction with clicker questions, collaborative worksheet activities, and think-pair-share; (3) reflections on learning such as two-minute papers at the end of class; (4) new methods of assessment such as standardized pre-/post-course testing of learning each year, two-stage exams, and graded homework; and (5), pre-class reading or other activities with quizzes as preparation for upcoming class. The specific combination of practices adopted by any particular instructor varied according to individual preferences and departmental interests. To be classified as a "large change" change in instruction required the adoption of #1 and #2, and most large change cases included additional improvements. The full range of improvements is largely reflected in the list of elements on the Teaching Practices Inventory that received points for demonstrating improved learning in research studies.[3]

Number of Courses and Faculty Changed

Table 5.2 shows the total numbers of courses and faculty changed by the SEI at the University of Colorado at Boulder (CU) and the University of British Columbia (UBC).

The SEI clearly has had a substantial impact on the educational experience for the students at these two institutions. The teaching of 71 courses at CU and 164 courses at UBC has been changed as of August 2015. By the time this book is published, those numbers will be higher. In ten of the twelve SEI departments, well over half the credit hours provided by the department are now taught quite differently, and in total about 200,000 student credit hours per year (139,000 at UBC and 53,000 at CU) are now being delivered using substantially better teaching methods than before the SEI. More than 250 faculty members are teaching differently as a result of the SEI, and in seven departments this includes more than 50 percent of the regular faculty. Even in departments where only a relatively small number of faculty have made changes in their teaching and a small number of courses were changed, the teaching of a large fraction of the student credit hours being taught by the department was affected.

Reasons for Variations in Results between Departments

The best indicator of the overall impact on teaching and departmental culture is the fraction of the faculty that have made large changes in their teaching. This indicates both a willingness to consider thinking about teaching in a different way as well as learning how to actually teach differently. The fraction of department faculty that have made such changes in their teaching varies between 10 percent and 93 percent.

Table 5.2. Impacts on courses, students, and faculty teaching

CU	Impact on courses		Impact on students		Impact on faculty teaching			
	# Large change	# Significant change	# Credit hours changed (in thousands)	% Credit hours changed	# Faculty total	# Large change	# Significant change	% Change
CHEM	6	1	14.1	58	53	8	0	15
GEOL	11	7	6.3	73	32	19	5	75
MCDB	8	4	7.2	65	34	9	8	50
IPHY	7	4	9.4	72	26	12	5	65
PHYS	7	1	1.8	7	50	12	8	40*
EBIO	9	6	14.2	75	35	14	2	46*
Total	48	23	53			74	28	

UBC	# Large change	# Significant change	# Credit hours changed (in thousands)	% Credit hours changed	# Faculty total	# Changed	% Changed
EOAS	32	16	14.8	85	46[a]	43	93
PHAS	18	7	19.5	75	61	34	56
BIO	19	8	35.5	62	118	43[b]	36*
STAT	8[c]	1[c]	6.5	83	16	14[c]	88
CS	21	6	24.8	86	45	28	62
Math	5	10	20.2	38[d]	67	7	10
Other[e]	7	6	18.0			11	
Total	110	54	139.3			180	

Table 5.2. *(continued)*

Notes: "# Large change" is the number of courses in each department in which there have been major changes in the course design, instruction, and assessment, following the SEI model, while "# Significant change" means that there have been at least good learning goals adopted and there has been significant change in teaching methods, such as adding regular use of active learning in the classroom. "% credit hours changed" is the percent of the annual credit hours taught by the department that are now being taught differently. The impact on faculty section gives "# Faculty total," the total number of regular faculty in the department who regularly teach (although not necessarily regularly teach undergraduates; that breakdown is not available), and "# Changed," the number of faculty who have worked to changed their teaching in a substantial way. At UBC, in most cases this involves working with an SES to completely transform a course. At CU, there was a larger variation in the extent of changes adopted by the faculty, so these are broken out into two categories.

a. This does not include three faculty who have indicated they will retire within a few years and so were phasing out of undergraduate teaching.

b. Of the three biology departments—botany, microbiology and immunology, and zoology—there is substantial variation in the degree of involvement, with botany faculty most heavily involved and microbiology least.

c. As discussed in this chapter, a number of faculty in this department made substantial changes in their teaching with only minor consulting from SEI-supported staff, so good data on the full extent of the course transformations is not available. The actual number of courses that have been affected is higher than this. The number of transformed courses includes eight of ten courses offered by the department at the 100, 200, and 300 levels.

d. 90 percent of this impact involved adding recitation sections with guided group problem-solving and computer-graded homework to the first-year courses. Although this was a significant and beneficial change, for the courses in other departments the changes to instruction are considerably more extensive.

e. Includes four general science courses that were created in the transformed format; the remaining courses are in chemistry supported with a pilot grant.

* These departments are special cases, so this percentage does not fully represent the extent of change.

From examination of the regular reports of the SESs, discussions with SEI departmental directors and department chairs, and many conversations with faculty, the reasons for these variations can be understood, and they offer many lessons for any effort trying to bring about institutional change in undergraduate teaching.

To a large extent, these variations simply reflect the level of success at consistently implementing the three essential elements of SEI teaching transformation:

- An SES with the necessary training and disciplinary knowledge
- A faculty member willing to work collaboratively with the SES to transform a course, and in the process try new teaching methods and ideas
- A teaching assignment that has the willing faculty member (and/or collaborating faculty members) teaching the course for the necessary number of terms to successfully carry out the transformation

There have been failures with achieving each of these three, but the second was the most frequent source of problems. All the SEI departments have also found it challenging to achieve the level of planning and organization needed to have multiple SESs within a department all consistently working effectively and efficiently.

The extent to which all three elements were achieved depended on many details of how a department operates and how they ran their SEI activities. The comparisons of the different departments have been very useful for elucidating the factors that affect success. I see three natural divisions of the departments: low performing (10–15 percent faculty change), high performing (50–75 percent), and excellent (88–93 percent). In addition, there are a few special cases where these percentages do not accurately reflect their achievement.

Low Performing Departments

The low extremes, 10 percent of the faculty changed in the math department at UBC and 15 percent in the chemistry department at CU, are dramatically lower than any of the other departments. The gap is somewhat larger than it appears in the table, as the next three departments are special cases with artificially low percentages. For both UBC math and CU chemistry, the numbers are also even worse than these percentages indicate, as instructors who are not regular tenure-track faculty make up an unusually large fraction of the faculty that changed their teaching methods—four of the eight for CU chemistry, and three of the seven for UBC math.

In the case of UBC math, this failure to achieve change is clearly associated with the culture of the discipline and the department. The regular tenure-track math faculty were extremely resistant to changing their teaching methods. Most of the changes came through working with instructional faculty who were not regular tenure-track research faculty, or by adding beneficial practices that the faculty had little involvement with, such as recitation sections with active learning added to courses.

It appears that math as a discipline is highly traditional in its teaching and more resistant than other STEM fields to adopt research-based teaching methods. For example, nearly all math departments still insist on using chalk and chalkboards for all teaching; the discipline has other strongly held traditions and views about teaching and learning. The culture of the department with regard to undergraduate education is also reflected in two other observations. First, the bulk of the department teaching is in the form of large introductory service courses. The tenure-track faculty have little involvement with these courses, which are predominantly taught by graduate students and postdocs as a condition of their employment. The postdocs have little teaching experience and little incentive to teach well; and most are from foreign countries and have little familiarity with the UBC students or the educational system.

A second indicator of the unique perception of undergraduate education held by the math department comes from a survey given to all the SEI departments. In a survey of instructors asking what they believed to be the primary impediment to improved student learning, the instructors in math overwhelmingly said the main impediment was shortcomings in the students (preparation, skills, or work habits). Instructors in other departments also mentioned student shortcomings as an impediment, but far less frequently.[4] These factors suggest that there is a general view in the department (and possibly the discipline) that undergraduate education in general is not an important activity and not one where they should be investing time and effort to try to improve. It is possible that another contributing factor to the resistance to change is that math is not an empirical discipline, unlike the rest of science and engineering, and hence is less persuaded by experimental studies of teaching methods and student learning. I recognized from the beginning that it would be challenging to make progress in improving the teaching of math, but I attempted this as an experiment because the need and opportunity for improvement was so conspicuous at UBC. Also, there was a new and particularly effective chair who expressed strong commitment to the effort. Unfortunately, that person took another position not long after the SEI funding was provided to the department.

In spite of these structural elements, there have still been indications of progress. After several years of SEI support and encouragement, several regular faculty have now been making changes in their teaching methods, and a group of graduate students have become active in learning about and implementing new teaching methods.

In CU chemistry, only 15 percent of the regular instructional faculty made any changes in their teaching, and only half of those were tenure-track faculty. The failure here was again the lack of faculty willing to participate. Unlike the UBC math department, the lack of success in the CU chemistry department did not seem to be so ingrained in the discipline, but rather stemmed from problems with the general functioning and culture of this particular department. There are long-standing deep divisions within the department, and so the department struggles to come to a consensus and make a unified effort on many issues. The faculty have a host of ongoing concerns that occupy much of their time and attention, making undergraduate education a low priority. There is no position of authority within the department that is responsible for overseeing undergraduate education. Finally, the chairs turn over quickly (every two to three years), and the new chair who came in after the SEI had started was not supportive of the SEI program. He showed no hesitation in reneging on the commitments made in the department's SEI proposal that had been put forward by the previous chair.

This department was funded before we realized the need for more specific commitments in terms of which courses and faculty would be involved. Although the department had voted to support the SEI proposal, it later became clear that few faculty members were involved in the SEI planning or discussion, or were themselves willing to participate in SEI course transformation activities. While many agreed that improvement was possible and needed, few had interest in spending time on it, and the department was unwilling to provide incentives for such activities. Funding for the department was phased out, although the decision and timing were complicated by the fact the SEI was supporting major improvements underway in the large introductory courses, something we were anxious to preserve.

Although this was clearly a failure to achieve the widespread change that was the goal of the SEI, there was nevertheless a substantial benefit to students. These changes substantially improved the teaching of 58 percent of the credit hours taught by the department. That is because the department teaching load is heavily based on large introductory courses, and most of the small number of regular faculty and non-tenure-track faculty involved with those courses were enthusiastic about participating in the SEI efforts. I do worry about the long-term sustainability of the educational improvements made in that department, however, when there have been so few faculty involved.

Special Case Departments

In terms of the fraction of faculty that made improvements in their teaching, there is a large jump up to the next group of three departments, in which 36–46 percent of the faculty made substantial changes in their teaching. However, all three of these are special cases, and so a direct comparison of these percentages with the other departments underrepresents their levels of success.

The CU ecology and evolutionary biology department must be considered a success, in that it first received SEI support several years after the other departments and with a lower level of funding, but it already has 46 percent of its faculty teaching differently. Their results for both credit hours and fraction of faculty changed are impressive for such a short time, and both those numbers are continuing to increase. Looking in more detail at how the department functions and how the SEI efforts were run, this department shares most of the characteristics of the most successful SEI departments discussed below.

The CU physics department is an SEI anomaly in that, by design, the SEI effort focused on changing the teaching of only a small set of upper-division courses for majors. That is the reason it has impacted a low fraction of the credit hours relative to the other departments. The main reason for this focus is that, prior to the CU SEI, all of the department's large introductory courses had already been transformed much along the lines of the SEI model, along with the teaching of many of the faculty. Thus this particular departmental effort was intentionally quite different from other SEI efforts from the beginning. Not only was it unusual in focusing on a small set of upper-division courses, but the effort was led by a single faculty member who had substantial outside funding for physics education research connected with the effort. It is notable that an effort that targeted such a small number of upper-division courses has managed to impact as large a number of faculty members as it has. One reason for this is the unusually frequent rotation in the instructors teaching these courses compared to the frequency of rotation for upper-division courses in other departments; most upper-division science courses at CU and UBC have very little rotation and are hard to transform. Another difference in the CU physics SEI effort is that many of these faculty are using materials developed and given to them for teaching a specific course, but unlike most other SEI course and teaching changes, these faculty participated little in the design of the course transformation itself. There is evidence that this has resulted in less sustainability of the changes.[5]

The UBC biology program had 36 percent of the faculty change their teaching, but behind this number is a more complex story, largely demonstrating the importance of basic organizational structure and leadership. It was one of the first two programs funded at UBC, in part because on paper it had an established organizational structure for overseeing coordinated undergraduate education and instruction across the three biology departments. In fact, the structure existed only on paper. Instead of the three departments jointly running the program, in reality no one did. The people who taught the lower-division courses, many of them long-term sessional instructors, were left to do as they pleased, and no one felt able to exert any authority over them, particularly as there was such a long-established precedent for not exercising any supervision or authority. This was particularly problematic because most of these courses were multiple-section, multiple-instructor courses, with each instructor acting independently, even to the extent of covering their own chosen set of topics and giving their own exams. These structural problems resulted in SESs struggling to work with these instructors but making very little progress, and ultimately quitting to take other jobs. While the department chairs expressed concern and a desire to change things, they felt unable to do so within the existing structure. In response to these problems, we greatly reduced SEI funding to the biology program.

Over the subsequent few years, with considerable input from the dean, the organizational structure of the biology undergraduate program was changed and good people were put in positions that now had clear responsibility and authority. They developed a clear plan for the development/transformation of a set of courses that would reshape the biology curriculum, including identifying the faculty members who would have responsibility for laying out what would be taught in those courses and the pedagogy used, aligned with the SEI goals. In response, we reinstated their funding, and since that time the progress has been good. They have systematically changed the curriculum and teaching methods of many large courses, which now provide more than 35,000 credit hours per year and involve forty-three faculty members. The process is coupled to a curriculum reform, which involved a shift in responsibilities of the three participating biology departments. While this reform complicates the SEI work in some respects, it also has benefits in making it part of a larger effort. Although at 36 percent the fraction of the faculty that have changed their teaching appears low, this is slightly misleading, as that fraction is the total across all three biology departments, but the botany department is now taking a larger responsibility for undergraduate education within the new alignment and has a large fraction of faculty involved, while the microbiology department has relatively little responsibility and few faculty involved.

The biology program has provided a dramatic example of how the organizational structure by which an undergraduate program is run can have a large impact on the quality of the program and how it can (or cannot) innovate and thrive.

High Performing Departments

These departments have had 50 percent or more of their faculty change their teaching, and two-thirds or more of the credit hours provided by the department are being taught using research-based methods following the SEI model. Within each of these departments are a variety of different situations that affected the degree of success and explain why they are not at the 90 percent level of the most successful SEI department. All have had some difficulties with departmental planning and management of the SEI efforts, and all have little rotation of teaching assignments among upper-division courses. This lack of rotation leaves some faculty with teaching loads dominated by the teaching of one or two upper-division courses, which they are seen as "owning." As discussed below, this pattern of teaching assignments can leave such faculty quite isolated from broader considerations and interest in undergraduate education, which limits the fraction of faculty impacted by the SEI. In addition to these common features, each department has some special challenges of its own.

UBC physics and astronomy (PHAS) had a particularly problematic organizational structure in which historically essentially everything was done by the chair with little delegation, including the running of the department's SEI effort. For such a large and varied department, even without the SEI this is an impossibly difficult job. It meant the attention devoted to the planning and structure of SEI activities and to oversight and guidance of the SESs was inadequate. This resulted in a substantial amount of SES time (and hence SEI funding) being used ineffectively. A special challenge for this department was that it focused much of its effort on changing the large introductory courses, which, like in the biology program, are multiple-section, multiple-instructor courses where the instructors have become accustomed to acting independently. Although it involved substantial work and several false starts due to insufficient planning and oversight (not ensuring that all the involved instructors were either committed to the effort or replaced), eventually PHAS was successful in transforming these courses. They have now established a common mode of quality instruction and content, which new faculty now rotate into and adopt. This is a major accomplishment.

CU molecular, cellular, and developmental biology (MCDB) has achieved changes by 50 percent of its faculty, impacting 65 percent of the credit hours. The main limitation on achieving wider impact within this department is that teaching loads are relatively light, and many of the tenure-track research faculty primarily teach only their particular upper-division specialty courses. As noted, such courses and faculty are particularly difficult to change. This department's SEI efforts have also been limited by a uniquely difficult personnel conflict, which tends to disrupt any attempt to arrive at departmental consensus and actions, particularly when teaching is involved. This personnel conflict is also an ongoing distraction to the chair, dominating the time and attention that the chair can put into the SEI and taking away from more constructive activities.

CU integrative physiology (IPHY) has been quite successful, at 65 percent of the faculty changed and 72 percent of the credit hours. The department had a supportive chair and receptive faculty. It likely could have achieved a larger impact among the faculty if the SEI departmental directors had been more aggressive about planning course transformations and recruiting and incentivizing faculty to participate, particularly those who primarily teach upper-division courses.

UBC computer science (CS), with 62 percent of the faculty and 86 percent of the credit hours changed, has been successful, but CS has followed an approach rather different from the other departments. They have had much more difficulty hiring SESs than other departments, because of the strong industry competition for people with CS skills. They also struggled for several years with departmental leadership. The chair had difficulty getting the faculty to work together, with the desires of individual faculty members taking precedence over departmental plans and commitments on various educational changes and planned SEI activities. Although there was some initial progress, it was relatively slow. A significant early accomplishment was the creation of learning goals for their first- and second-year core courses. After some changes in leadership, they ended up with an effective and committed chair who worked productively with the SEI department director, and they solved the SES problem.

The solution was to use a different model, with much of the SES activities done by tenure-track teaching faculty who historically have played a large role in the department and are well respected. Using SEI funds, the department bought out some of the teaching time of these instructors so that they had time for more training about science education research and for serving as SES consultants to the rest of the department. These SES instructors also took the lead in establishing learning goals for the main academic streams of CS majors and mapping these goals onto the courses in that stream. This generated discussion with many faculty as to the educational goals of these tracks and the courses involved in them, and how well these goals were being met. CS was also different from other SEI departments in that it used a larger fraction of its SEI money to support many smaller teaching projects that individual faculty would propose and carry out with SES consultation and advice, rather than supporting full scale course transformations. Through this process many faculty have adopted new teaching methods and many SEI course elements, without extensive course transformations supported by an SES.

In *CU geology,* 75 percent of the faculty have changed their teaching, and 73 percent of the credit hours have been impacted. This department had a supportive chair and a receptive faculty, with some strong faculty proponents. A factor that likely helped was that nearly all of the faculty in the department cycle through teaching the two large introductory courses, which provide a large fraction of the department's credit hours; SESs could reach most of the faculty through these courses. One area for possible improvement would have been better training of the SESs. In the most successful departments, we saw that the SESs would find particular opportunities for instructional change that would result in immediate and obvious improvements in areas of concern to the instructors. This would convince the instructors of the value of these research-based teaching methods, and they would talk about them to their colleagues. In CU geology, however, the early changes resulted in less obvious improvements and had little emotional impact on instructors. I worry that this may have affected the willingness of faculty to sustain and build on instructional changes in the future. In later SES training, we added an emphasis on the need to learn the instructors' concerns and find interventions that would directly target them, but CU geology was the first department to be funded and to hire SESs, and at that time the SES training program was immature.

Excellent Performers

UBC statistics is a very small department with a correspondingly low level of SEI support, but which they have used to good effect. They have a lot of rotation in teaching assignments, with nearly all faculty teaching the courses that provide most of their credit hours. Thus nearly 90 percent of their faculty have changed their teaching. Also, in addition to SES-driven efforts to make changes in courses, there have been a few senior faculty who made major changes in their teaching, after discussion with other faculty and SESs, but with little direct SES support. The result has been a general overall change in how the faculty in the department teach and talk about teaching. Few upper-division courses have been changed as an SEI effort, but there may be faculty who have changed how they teach those and we are not aware of it because of the limited SES presence and reporting in the department.

The UBC Department of Earth, Ocean, and Atmospheric Sciences (EOAS) was clearly the most successful large department at achieving widespread improvement in their teaching. Nearly all of its courses have been transformed and nearly all of its faculty have adopted new teaching methods. The level of success enjoyed by this department deserves a closer investigation, which I take up in the following section.

What Made the UBC EOAS Department So Successful

The following is a description of the set of elements that were put in place as part of the EOAS SEI effort. I see these elements as providing a model for success in any program that has goals similar to the SEI's for improving teaching.

Teaching Initiatives Committee. A new, permanent Teaching Initiatives Committee (TIC) was established to plan, coordinate, and guide the SEI program. The chair of this committee became the department's SEI director. (Note that this is not the curriculum committee; the TIC is tasked with overseeing teaching initiatives within the department and does not have the role of approving curriculum changes.) In addition to the SESs and the SEI department director, the committee includes two or three other long-term faculty members, and usually graduate student/TA and undergraduate representatives. The TIC provided a good guidance structure and the SEI department director led the program in a very competent, organized, and thoughtful way. Later in the program the department director took a one-year sabbatical, but the program was well established by that time and was capably managed by long-term SESs during the director's absence.

Consistent strong leadership and support. Although the department chair changed twice during the SEI program, all of the chairs were very supportive of the SEI efforts. Among many other supportive actions, the chair made it explicit that if faculty student evaluations go down during the course transformation process, the chair would take responsibility for contextualizing those evaluations in promotion and tenure processes. (In reality, evaluations usually stayed about the same.) The chair also often put items relating to the EOAS SEI on the agenda of faculty meetings and retreats.

Detailed planning. A detailed plan was developed by the TIC, identifying which courses and faculty would be involved in transformations and what the timeline would be. This ambitious plan was designed to involve as many faculty as possible working with SESs in an efficient manner. It served as an overall guide for the program, listing which courses would be transformed, and breaking the transformations down into planning, teaching, and second teaching terms. The plan evolved during the program but kept its original scope and intent. The plan as of January 2009 is shown in Figure 5.1.[6] One factor that was different in EOAS compared to the other science and math departments at UBC and may have simplified its planning process is that it does not have any large required service courses (i.e., courses that are required for students majoring in other disciplines). EOAS does have a large elective course (EOSC 114) that was successfully transformed early in the program. It has an enrollment of about 650 per term and has multiple sections and sequential instructors, with one instructor clearly in charge, which helped make the process go smoothly.

Science education specialists. All of the initial SES hires were internal people (former students, postdocs, lecturers). This was not the explicit plan, but it turned out that the best candidates were internal. This meant that the SESs were familiar with the department, and a subset of the faculty was familiar with each of them. Thus it was relatively easy to begin comfortable conversations about teaching, and get the course transformations started relatively quickly.

The EOAS SESs were all hired into temporary faculty positions. They attended faculty meetings and frequently participated in discussions about teaching and learning at those meetings. Two of them stayed on as SESs for seven years, each working with more than fifteen faculty members. At the end of SEI funding, these SESs continue to be employed in EOAS, and a number of EOAS faculty members continue to consult them on teaching issues. There were also a number of other SESs hired; during the middle four years of the program, there were typically four SESs working in the department, each working with two to four faculty members.

While this department has been quite successful with internal people becoming SESs, we do not feel this is necessary for a successful SEI department. In looking across the SEI departments as a whole, we have found that external SESs can also be very successful, but it usually takes longer for them to become familiar with a department and develop good working relationships. On the other hand, external people can bring experience and perspectives that might be lacking internally.

Direct incentives to faculty members. At EOAS, the SEI had a menu of possible incentives to faculty in order to get them to put in the work necessary to transform a course. This included, for each of three terms (one planning term plus two teaching terms), either (1) a 0.5-course release, (2) a six-hour-per-week extra TA, or (3) something equivalent that would take work off the faculty member's plate, such as partial support for a research assistant.

As of 26 January 2009

EOS-SEI LONG-TERM PLAN

UPDATED DRAFT, STI LL FLEXIBLE

P1 = first planning term; P2 = second planning term; T1 = first teaching term. etc.

TARGETED COURSES	2007	2008			2009			2010			2011		
	Fall07	Spr08	Sum08	Fall08	Spr09	Sum09	Fall09	Spr10	Sum10	Fall10	Spr11	Sum11	Fall11
EOSC 114	P2&T1	P3&T2	P3	T3	T4								
EOSC 111	P2&T1	P3&T2	P3	T3	T4								
EOSC 221	P1	T1	P2	P2	T2	P3	P3	T3					
EOSC 324	*MLB*												
ENVR 200	*DS&SH*												
EOSC 112		P1	P1	P2&T1	P3&T2	P3	T3	T4					
EOSC 220		P1	P1	T1	P2	P2	T2	P3	P3	T3			
EOSC 212		P1	P1	T1	P2	P2	T2	P3	P3	T3			
EOSC 210		P1	P1	T1	P2	P2	T2	P3	P3	T3			
EOSC 116		*SS*											
ENVR 300		*DS&KC*											
332 (JM)				P1	T1	P2	P2	T2	P3	P3	T3		
322 (GO)				P1	T1	P2	P2	T2	P3	T3			
355 (CJ)				P1	T1	P2	P2	T2	P3	T3			
EOSC 449				*MLB*									
ENVR 449				*KO*									
ATSC 201				*RS*									
EOSC 211 (RP)					P1	P1	T1	P2	P2	T2	P3	P3	T3
EOSC 372 (SA)					P1	P1	T1	P2	P2	T2	P3	P3	T3
EOSC 373 (MM/others)							P1	T1	P2	P2	T2	P3	P3
EOSC 252 (FH)							P1	T1	P2	P2	T2	P3	P3
EOSC 472 (KO)							P1	T1	P2	P2	T2	P3	P3
EOSC 321 (MK)								P1	P1	T1	P2	P2	T2
EOSC 331 (KH)								P1	P1	T1	P2	P2	T2
EOSC 326 (SS)								P1	P1	T1	P2	P2	T2
EOSC 329 (RB)								P1	P1	T1	P2	P2	T2
EOSC 222 (PS)									P1	P1	T1	P2	P2

Courses undergoing transformation w/o specific STLF help

Course sequence considers: logical progressions, breadth in EOS, faculty keenness
" aims for: maximum departmental involvement
" interfaces with: teaching assignments, scheduling, & sabbaticals

FIGURE 5.1. The EOAS-SEI long-term plan

Note: Name was changed from EOS to EOAS partway through the SEI.

Table 5.3. EOAS course transformation expectations agreement

	By end of planning term	By end of first teaching term	By end of second teaching term
Project scope	Outlined	Revised	In final documentation
Course-level learning goals	Draft: involve stakeholders	Revised	Broadly accepted
Module- or lecture-level learning goals	Draft	Revised	Mapped to course learning goals
Assessment	Draft plan	Revised plan and materials	Optimized plan and materials
Teaching methods (pedagogy)	Draft plan	Revised plan and materials	Optimized
Short summary of structure and rationale		Draft	In final documentation
Materials archived			Completed
Plan for sustainability			Completed
Share progress/problems	Annual or semiannual mini-retreat		

Agreement on responsibilities. An agreement was also developed to give faculty a detailed understanding of what would be expected when they participated in a course transformation. This agreement was signed by the faculty member and the department chair. Table 5.3 shows the expected elements for each of the terms of a course transformation as laid out in the agreement.[7]

Progress reports and regular meetings to discuss progress and strategies. The EOAS SEI department director would meet with the SESs weekly, regularly providing suggestions, offering guidance, and monitoring progress. Regular meetings between the department director and SESs happened in other UBC SEI departments as well, but the EOAS meetings were particularly focused and well aligned with advancing the departmental

SEI program goals. In addition, short written progress reports (initially twice per month and later monthly) were also required of all the SESs. These were typically discussed at a monthly meeting that included the SESs, the SEI department director, and the UBC SEI director.

Teaching assistants' development. The EOAS SEI developed a course for graduate TAs: EOSC 516, Teaching and Learning in Earth and Ocean Sciences. The course was designed to improve the teaching skills and knowledge of effective pedagogy of the TAs. The course is now run primarily by graduate students who have facilitator training, and has an enrollment of about fifteen students per year.[8]

Involving undergraduate and graduate students. In addition to the involvement of graduate students in the running of the TA training course described above, twenty graduate students were supported by SEI funding to be involved in improving courses under the SEI, ranging from redesigning laboratory courses to developing learning goals and in-class activities. Ten undergraduate students were involved in various aspects of the EOAS-SEI, and three of them completed geology honors theses based on their SEI-related educational research.

Communication within the department. The department as a whole discussed and approved each of the key planning and implementation documents used in the project—for example, the long-term plan, the incentive agreement, and the course transformation expectations agreement. Thus these key components weren't implemented without an opportunity for everyone to have input. Broader departmental involvement was fostered via brown-bag seminars on education (which had only modest attendance), invited speakers in geoscience education research as part of the normal departmental seminar series, regular SEI postings on the departmental bulletin board, and the *EOAS-SEI Times* newsletter. The monthly newsletter reported on SEI accomplishments and progress and was put into faculty mailboxes and posted on the departmental website.[9] Seminar topics included discussion of effective clicker use, attitudinal survey results, midterm and end-of-term surveys, improving exam questions, online discussions as a learning tool, critical incident questionnaires, assessing geoscience programs, and just-in-time teaching. The EOAS SEI program also maintained a website that gave details of the projects being done under the SEI as well as resources for faculty members.[10] Finally, some respected senior faculty became conspicuously involved with the SEI early on.

For several years the department had an annual SEI mini-retreat in April. During that half-day event, all the EOAS instructors currently involved in SEI would meet to share and discuss what they had been doing in their courses. This allowed a space for busy faculty members to talk to and learn from one another about teaching, which seldom happened spontaneously during the academic terms and across the many subdisciplines in EOAS. However, by the end of the SEI such spontaneous discussions had become far more common than they were at the start. The SEI work was also an explicit topic of discussion at the annual departmental one-day retreat for the first four years of the project, and again during the year of transition to the post-SEI era.

In addition to other resources provided to the faculty, SES Francis Jones spearheaded the creation of the Evidence-Based Science Education in Action video series.[11] These professional videos show a variety of innovative teaching methods in use in real EOAS, math, and physics classes. The videos came with supporting materials to provide context, instructor's tips, and pertinent references.

Each of these ten components listed contributed to the success of the SEI effort in EOAS Rather than any single critical element, I believe it was the thoughtful combination of all of these elements that is unique to this department that made this department's SEI efforts so successful. The success was as a result of having committed people in positions of authority who understood how to manage organizations and the people involved.

Teaching Practices Inventory Data for Departments

Another source of data on the teaching changes accomplished at UBC by the SEI is provided by the Teaching Practices Inventory. TPI data exists from the UBC SEI departments for the 2012–2013 year.[12] In keeping with the challenges discussed in Chapter 3 about getting departments to collect data, it was difficult to convince departments to require faculty to fill out the TPI survey. For UBC, only EOAS and CS set the expectation that all faculty should do this, and hence obtained a sufficiently high compliance rate (about 90 percent). For CU, we received only a handful of responses. Only for UBC EOAS do we have adequate data for both 2006–2007, when

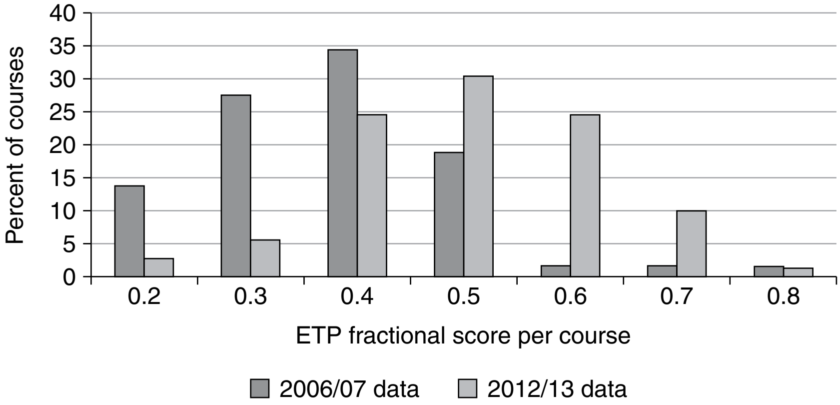

FIGURE 5.2. ETP scores for courses in EOAS

This histogram shows the fractional ETP scores for the courses in the UBC EOAS department in the 2006–2007 and 2012–2013 academic years. The survey was slightly different for the two dates, so the scoring is the fraction of the maximum possible score based on the subset of forty scored questions common to both versions of the inventory. (See note 3 in this chapter.)

the SEI was just beginning, and 2012–2013, so we can examine the change. As shown in Figure 5.2, there is a substantial increase in the TPI scores, representing a substantial increase in the extent of use of research-based teaching practices (ETP). The comparison between CS and EOAS 2012–2013 TPI scores shows that they are similar overall, although a more detailed analysis of the different categories shows more variations. The overall similarity is consistent with Table 5.2 showing that there have been changes in teaching in both departments for a large fraction of their courses and credit hours.

Sustainability

While it's unclear whether the transformations carried out in the courses and the changes in teaching methods of individual faculty members will be sustained, there is short-term data on this from the departmental annual reports and some surveying of the faculty. These indicate a high level of sustainability at UBC. A 2013 survey of the seventy faculty members who had adopted substantial changes in how they teach as part of the UBC SEI program and then had at least one subsequent year teaching without any SEI support showed that all but one of the seventy had continued to use the new methods they had adopted.[13]

Furthermore, in that same survey, 90 percent of the faculty who subsequently taught a different course without SEI support reported that they had adopted some or all of these novel teaching methods in that subsequent course.

There is some indication from the CU physics department that faculty who adopt methods and materials to teach a transformed course but never actively participate in the design process for transforming a course are less likely to sustain the use of new teaching practices.[14] However, there are also a few examples of faculty getting a brief and relatively superficial exposure to new teaching methods, but then over the course of months or years embracing them more and taking time to understand and use them effectively. To truly know the extent of sustainability of the SEI impact on teaching, it will be necessary to wait and watch.

I suspect that the fraction of the faculty—particularly the regular tenure-track faculty—that have adopted research-based teaching methods in a department will likely be a good predictor of departmental sustainability. I am concerned about sustainability in those departments where fewer than 50 percent of the faculty members have adopted new teaching methods, even if the teaching of most of the credit hours has changed. As noted, there are several departments where a significant fraction of the faculty teach only specialized upper-division courses and have not made any changes. Although they may teach relatively few credit hours and in limited contexts, those faculty members still speak with an equal voice in hiring and promotion decisions and discussions about how teaching should be evaluated and rewarded. Departmental decisions on such issues will have long-term impacts on the methods and quality of teaching in a department. The smaller SEI program at CU has generally resulted in smaller changes in the departmental practices at CU than at UBC. I believe that this difference is likely to be reflected in differences in the sustainability of the improved teaching methods.

I know of one department (not surprisingly, UBC EOAS) that is making changes in the department's methods of evaluating teaching for merit, promotion, and tenure that are based on the department's SEI experiences. That suggests that sustainability of the use of new teaching practices in this department is very likely.

Faculty Attitudes about Teaching

Over the course of the SEI I learned a great deal about faculty and department attitudes about teaching and learning and saw many of these shift over time. Here I list the most notable observations. These are my personal impressions, but they are shaped by hundreds of conversations with faculty members, department chairs, SESs, as well as reviewing of large numbers of SES and departmental reports. I have become convinced that virtually all faculty want to teach well. I found that most faculty who use methods that are less than optimal may care as much about teaching as others do, but they are unconvinced of the value of changing. When they pursued actions counter to what we desired, there was no maliciousness in their actions; rather, it was the result of having different values and priorities, largely as a result of the incentive system and the culture in which they were working.

I also saw that nearly all faculty members can learn to use new teaching methods effectively, but there is a significant initial learning curve during which the faculty are learning what this form of teaching looks and feels like in their own class, as well as developing an understanding of the theory of learning on which it is based. While there were obvious variations in the speed and effectiveness with which faculty adopted the new teaching methods, the great majority became reasonably effective after working with a well-trained SES. In this regard, the SESs acted as coaches, sitting in on classes and regularly offering specific feedback and advice. This assistance was the most critical in helping faculty tackle the initial part of the learning curve. After that most faculty could function well and continue to improve on their own. The variations in the steepness of the learning curve among different faculty members could be largely explained by how knowledgeable they were as to the thinking of the students in their courses. The range of faculty attitudes about the adoption of teaching innovations that I observed has some agreement and some disagreement with prevailing wisdom. While faculty can be fairly well described by the general categories put forth by Rogers for adoption of innovations—early adopters, the thoughtful majority, and laggards—I found the distinctions to be rather fluid and time dependent.

Early adopters. These are the faculty members who were knowledgeable about discipline-based education research (DBER) and already implemented many of the ideas, or who had been reflecting deeply about teaching and learning and were increasingly dissatisfied with the results of their traditional methods of instruction. They saw the teaching methods espoused by the SEI as the solution they had been looking for. These faculty members often immediately and effectively put research-based teaching methods into practice. They valued the prospect of having an SES to partner with in this work. With such faculty members, SES work could focus on supporting the instructor as they incorporated the new teaching practices, and provide feedback on materials and implementation to allow for iterative improvement. These faculty members could also be cultivated as educational leaders within the department, speaking about their experiences and satisfaction.

One caveat is that we have found that a significant fraction of this cohort also like to emphasize the enormous (and usually unnecessary) amount of time they spent on their teaching. This is presumably an attempt to get greater credit and respect for their teaching efforts, but it can serve to discourage others from adopting new teaching methods. A second caveat is that it was not unusual for faculty members' stated beliefs to be inconsistent with their subsequent actions. For example, some instructors who portrayed themselves as early adopters were limited in what changes they would consider, and some self-anointed traditionalists turned out to be rather flexible and adopted new methods, sometimes even while continuing to label themselves as traditionalists.

Thoughtful majority. This group comprises the largest number of faculty members. The members of this group were not immediately convinced they should change their practices, or more specifically, that they should put in the time required to change. Usually they were concerned about the impact this would have on their research and were not sure the benefits were sufficient to offset that cost, but they were open to arguments to the contrary. They simply display the healthy skepticism with which scientists would be expected to treat any new claim.

Over a period of time the views of many of these faculty evolved as they were exposed to new ideas about teaching and learning and to data on results, whether through discussions in faculty meetings, hallway conversations with early adopters and other participating faculty and SESs, seminars, or articles and newsletters distributed within the department.

After such exposure, the typical next step was these faculty members would talk with an SES about possible changes to their teaching and/or observe a course being taught using novel methods. This was often the strongest argument for convincing faculty to change their teaching methods—seeing students far more engaged and interested in the material and asking many more, and deeper, questions than in their regular lecture classes. Observations of a class also helped reduce the common fear that allowing students to talk together to solve problems would lead to a loss of control of the class. Faculty were also able to see that substantial material could still be covered in a course taught using active methods, addressing a second common concern.

It was typical for many of these thoughtful skeptics to take a year or even two after a department had launched a full-scale SEI effort before they came forward saying that they would like to work on transforming their teaching. We learned not to prejudge which faculty members would be the most likely to support and participate in the SEI efforts, as many individuals defied initial expectations. After being exposed to SEI methods during this one- to two-year incubation period many decided to change, including some who had been thought by their department to be hopelessly traditional. The relationship of seniority to attitude change was also more complex than is often assumed. Although younger faculty may have been slightly more likely to buy into new teaching methods, there were some young faculty members who were strongly opposed to the basic concept, and many others felt this was something they should avoid until after they had tenure. On the other hand, numerous senior faculty members became very enthusiastic about the SEI methods.

Laggards. There are many references to this type of faculty member in the educational change literature, usually with comments to the effect that death or retirement is the only way to deal with them. I believe that such sentiments are too pessimistic, and that it is more appropriate to think of most of these faculty as simply the tail of the distribution of the thoughtful majority. In the most successful SEI departments, a number of faculty who had previously been seen as completely resistant to change eventually sought out SESs to help them with transformation of their teaching. In a few cases, there have been suggestions that student complaints about how much less they were learning in traditionally taught courses, compared to the transformed courses, might be a contributing factor. Educational innovations across the department can lead to such complaints, as students become accustomed to more effective teaching methods.

I do not believe that it is realistic to expect all of the laggards to change their teaching in response to an SEI type program, but I do think it is dangerous to prejudge how faculty members will respond based on their initial reactions and behavior. The reasons this group of resistant faculty act as they do are quite varied. Some have been recognized as good teachers on the basis of teaching awards given for their lecture performances and see lecturing as core to their identity as a faculty member; some feel they could never excite students in the subject and be effective teachers; and others see their real job as doing research, with teaching merely a minor side annoyance. Over the course of a few years, we have seen large changes in all of those attitudes, but not in every case.

So, while it can be useful to recognize the values and perspectives that are reflected in these conventional categories of adopters of innovation, care must be taken not to jump to conclusions about what faculty members will and will not do and why, based on how one has classified them. The beliefs and behaviors of individuals are affected by various formal and informal incentives and experiences, and these beliefs change over time scales of a year.

Institutional Contrasts in Attitudes about Long-Term SEI Impact

CU attitudes. As part of a small NSF funded external evaluation of the SEI, a CU researcher not involved in the SEI conducted in-depth, semi-structured interviews with samples of individuals involved in the change initiative: SEI leadership (including institutional administrators), project leaders, department directors, SESs, SEI-engaged faculty, and the chairs of SEI-participating departments. Interview protocols explored individuals' knowledge of the change effort, their role within it, their experiences in SEI, their attitudes and beliefs about teaching and learning, self-reported changes in these as a result of involvement in the change initiative, issues of autonomy, motivation, and resistance to SEI, and whether the initiative was seen as successful, and why or why not.

Individuals were solicited to participate in an interview, and those who agreed provided a letter of consent for the study via university email. Out of sixty-five individuals invited, fifty-four were interviewed. Interviews were conducted individually, lasted one to two hours, and were digitally recorded and transcribed. These data were released to two members of the SEI team, including myself, under a separate IRB protocol, dependent upon individual consent, with the provision that (1) the individuals would remain unidentified,

(2) administrators and former or current SESs employed at CU were not included, and (3) individuals were allowed to redact their statements. With these restrictions, a total of twenty-four agreed to release their transcripts to me.

The views reflected in these interviews were very consistent with my impressions about general CU departmental attitudes formed from previous discussions with CU SESs, faculty, and department directors. While most of the individuals interviewed were enthusiastic about the changes that had taken place in their departments, the great majority expressed the opinion that these new approaches to teaching and their benefits were not embraced by their department as a whole. Most communicated concerns about sustaining and building on these changes after the end of the SEI funding. There were also many comments expressing the general belief that the only thing that mattered in the department was research productivity, and after the end of SEI funding this emphasis would overwhelm any attention to teaching and education. It should be noted that these interviews and other sources of input did not involve the CU ecology and evolutionary biology department, as its SEI activities began rather late and appeared to be taking a somewhat different path from the other CU departments, with potentially more positive attitudes.

While there were many negative attitudes expressed about the sustainability of the SEI impact in CU departments, they may not entirely reflect the reality. In discussions with me and other members of CU SEI Central, some faculty members have expressed a lack of enthusiasm for the SEI concept, but then mention that they have adopted and planned to continue using a number of the teaching methods advocated by the SEI. Also, as SEI funding approached its end, all of the SEI departments expressed the desire to find some way to preserve an SES in the department, as they were seen to be of great value. One of the institutional differences was that this idea of preserving some SESs was not supported by the CU dean, whereas it was supported and ultimately funded by the UBC dean.

UBC attitudes. At UBC, our indications of departmental attitudes come from interviews with department chairs, SEI department directors, faculty, and, most of all, regular feedback from the SESs. While there is a spectrum of opinions, overall the views of the SEI and its long-term impact on departments are considerably more positive than at CU. (The comments below apply only to the non-math departments.) In the early years, the attitudes were similar to those expressed in the interviews at CU, but that changed over time. While there is now the general opinion that there are some faculty members who will probably never change their teaching or beliefs, the general attitude in the non-math UBC departments is that such faculty are now the exception rather than the norm. In the SEI departments there are now many faculty, including some highly respected ones, who regularly discuss the benefits and pleasures of teaching in these new ways, and a steadily increasing number of faculty who are embracing new teaching methods and seeking out help with their use. In large part because so many faculty members are so enthusiastic about these teaching methods and have colleagues around them who feel the same way, many in the departments are quite optimistic that these changes have become the norm within the department, even if they will not be used by everyone.

There are also other signs that this transformed teaching is becoming entrenched within the culture of the UBC departments. In most departments there are now ongoing discussions or established plans as to how new faculty coming into the department will be trained in the use of these teaching methods. A co-teaching program has been established in two large departments (EOAS, PHAS) in which funds are provided to support a faculty member highly experienced in these teaching methods to co-teach with a new faculty member (or in some cases senior faculty members) in order to develop their teaching expertise. The dean has recently established a program to fund a permanent SES-type position in each department, with the intention that these individuals will serve as expert consultants to faculty. This suggests a rather fundamental change in thinking about teaching, namely that it is an activity that involves true expertise that comes from knowledge and careful practice, rather than merely a matter of individual opinion and expression.

I believe that the reasons for these differences in attitudes at the two institutions are likely some combination of three factors. The first is the strong and conspicuous support by the UBC dean of sciences. Both within and outside the institution, the dean regularly discussed the SEI and what it was accomplishing, characterizing it as something to be proud of. He brought it up in his regular meetings with the department chairs, and when there were problems with a department's SEI work, he would discuss it with the chair. In his selection of new chairs, the candidate's support for the SEI activities was a significant factor, and so each new chair who came in was usually highly supportive and an effective leader. At the annual SEI miniconference, the dean and many of his associate deans were always conspicuously seated in the middle front of the auditorium, and he was very engaged, frequently asking questions of the speakers. It was also a fund-raising priority for the dean. At CU, none of these things happened, as the dean largely ignored the SEI, and most new department chairs at CU that were appointed during the SEI were neutral or opposed to its activities.

The second reason is money. The UBC SEI had about twice as much money as at CU. This meant that UBC departments had more money to use for hiring SESs and providing incentives to faculty to participate in SEI course transformations.

The third factor is better training of SESs and better management of the SEI in general. As noted above, the UBC SESs had more formalized and more extensive initial and ongoing training. There were also more of them and they had a much stronger sense of community and used this to enhance their knowledge and skills. Also, as I will discuss at length in Chapter 6, I learned a great deal about the changes needed in how the SEI functioned, and there was more opportunity to implement these changes at UBC than at CU.

Attitudes about Learning Goals: Contrasts between Institutions

The attitudes about learning goals offer a notable contrast between the two institutions. The extent of acceptance of learning goals for structuring and guiding courses and teaching varied considerably across departments at both institutions, but over time there has emerged an overall institutional difference. Learning goals are now widely accepted as the norm within most departments of the UBC Faculty of Science, but much less so in the science departments at CU. It has become routine for UBC faculty members to discuss courses in terms of the learning goals they desire to achieve, and to start the design of new courses with identification of learning goals, even when those efforts are not connected with the SEI. It is considerably less likely at CU for there to be good learning goals that instructors embrace and use. (The CU ecology and evolutionary biology department is a notable exception to this and in several other regards.)

This difference in attitudes is a large change from the start of the initiative, when there was considerable fear and discomfort expressed about the idea of having learning goals; discomforts that were nearly identical at both CU and UBC. The faculty had difficulty in articulating good learning goals, they felt that they would be too constrained by having learning goals, that showing goals to the students would result in complaints about the teaching and the exams, or that having such goals would necessarily make the courses more superficial. It should be pointed out that these common fears about learning goals are entirely in the abstract. I am not aware of any of them ever actually occurring in the hundreds of SEI courses that have learning goals that are available to the students.

I am not sure why the attitudes evolved differently at the two institutions, but I speculate that there are two main reasons. The first is that the dean at UBC mandated that there had to be learning goals for all the introductory courses that satisfy a college or university requirement (which includes courses in math, physics, biology, and chemistry). Second, there were more SESs in the UBC departments to assist with the formulation of good learning goals, and at UBC they were better trained on this than the SESs at CU. These differences resulted in more faculty actually going through the process of creating goals and using them in their courses. This resulted in their seeing the learning goals as more familiar and less threatening, and ultimately as beneficial.

It is interesting to note that, unlike UBC, there is an accreditation process at CU that requires such learning goals for all courses. However, for accreditation purposes usually one individual in the department creates and turns in to the appropriate office the goals for the courses, working largely in isolation. It is unclear whether this process causes the faculty to be more cynical and suspicious about learning goals, or whether most are simply oblivious to this part of the accreditation process.

While the original SEI vision was to create learning goals that reflected a departmental process and consensus, this almost never happened. I think this was because it was simply too difficult and unfamiliar a task and that it involved too much collective effort to be worth the perceived benefit. However, it is likely that many sets of learning goals that were created by an individual faculty member for their course will end up accepted as the de facto departmental goals. Whether future instructors of the course will use those goals to guide how they teach and assess students, and whether departments will monitor if that is happening, is unclear.

Economics of the SEI: Ongoing Costs, One-Time Costs, and Private Fund-Raising

In addition to tracking the impact of the SEI on teaching and departmental attitudes, we also collected data on instructional costs after the completion or near-completion of the SEI transformation efforts, and compared those to the pre-SEI costs. These data confirm the assumption of the SEI model, which is that providing more effective undergraduate instruction costs no more than traditional lecture instruction.

We also provide a brief analysis of the return on the SEI investment per instructional credit hour transformed, although that return was not a goal of the program. Finally, we include a short note here on our experiences with regard to fund-raising for an SEI-like enterprise.

Ongoing Instructional Costs after the SEI

Costs at UBC. About 180 faculty members significantly changed their teaching practices, changing the teaching of 140,000 credit hours per year. The original design of the SEI was that there would be substantial one-time transition costs, but that at the completion of that transition, the instructional costs would remain the same. These costs include the faculty and administrative salaries associated with the undergraduate courses and the cost of TAs. We have examined the changes in those costs as a result of the SEI activities. We have excluded the normal enrollment-driven adjustments from this analysis, as those are disconnected from the SEI activities. The changes in costs for UBC are listed in Table 5.4.

There was no change in the number and cost of instructional faculty or administrative support across any of these departments. There was no change in the number of TAs in statistics, math, computer science, or

Table 5.4. Changes in instructional costs at UBC

Department	Change in faculty and administrative costs	Change in TA cost
EOAS	None	Added training; increased cost about 2 TAs = \$12,500 per yr
PHAS	None	Added training and numbers; increased cost about 4 TAs = \$25,000/yr
Statistics, math, computer science	None	None
Biology	None	None (although reallocation)

biology, and hence no change in ongoing costs in those three departments. There was some small reallocation of TAs, largely to be somewhat more rational. For example, in biology it was realized that the ratio of TAs per credit hour was roughly twenty-five times higher for upper-division courses than for lower division courses, and so there was a small reallocation of TAs to lower division courses as SEI transformations were carried out.

EOAS and PHAS both introduced TA training programs. Led by mentor TAs, these programs are run in the week before the term starts and have some follow-up during the term. This training costs the equivalent of two TAs per year. PHAS also increased the number of TAs assigned to introductory courses by two to help manage the logistics. So, the net increase in instructional costs to these two departments is about two to four additional TA salaries per year.

One might debate whether the additional TA training costs were actually driven by the change in teaching practices. Many university departments have such TA training programs regardless of the teaching methods in use, as did some departments at UBC before the SEI, such as computer science. However, EOAS and PHAS did not have such programs before the SEI, and it would be difficult to maintain the current teaching without this TA training.

Costs at the University of Colorado. As at UBC, there were no changes in the faculty or administrative costs for teaching in any of the SEI departments. There were only two additional SEI-related costs. The first of these is that MCDB added recitation sections to the large intro course, requiring several additional TAs. This change was made after using SEI funds to fund an experiment that showed these recitation sections had significant benefits for student outcomes. Also, as a result of the SEI, the department became aware that such sections were standard practice for introductory science courses at the university.

The second additional cost at CU came from the addition of undergraduate TAs in a number of courses across the SEI departments. This was done as part of the learning assistant (LA) program,[15] a program whose primary purpose is to recruit science majors to become K-12 teachers. The LA program provides students with early teaching experiences helping in undergraduate science courses and pays them $1,500 per semester while they work as undergraduate TAs. Undergraduate LAs have been integrated into eight of the SEI-transformed courses. Whether they should be considered an added cost is debatable, because supporting undergraduate instruction is only a secondary goal of the LA program, and the majority of the LAs are working in courses that were not part of SEI transformations. In any case, the costs per SEI department for this LA program are small, typically several thousand dollars per year.

In summary, the ongoing instructional costs before and after the SEI transformations are essentially unchanged at both institutions. The primary additional costs have been for TA training.

This analysis includes all the defined costs. There is also the amount of time that the faculty spend on their teaching, which some might argue is a cost that has increased as a result of the SEI, but I do not believe that it is possible to quantify such claims. The job descriptions, standards for hiring and promotion, and the institutional accountability and incentive systems at both these institutions have remained unchanged. So from an institutional perspective, how much time an instructor spends on teaching and how they teach was, and continues to be, entirely a matter of individual preference, with no connection to institutional accountability. Some faculty spend enormous amounts of time on preparing and later modifying highly traditional lectures, while others are using teaching methods introduced by the SEI in an effective way while spending very little time on preparation. From an institutional perspective, none of this is reflected in the instructional cost.

One change that has resulted in a some faculty members spending a little more time on teaching than before the SEI is the addition of homework in courses where previously there had been none. It came as a surprise to me that such courses without homework existed in the sciences, as the educational benefits of required homework are well established. I have since realized that this is one of the areas that differ significantly between disciplines, with physics and computer science having strong traditions of regular graded homework, and biology and earth sciences often only having suggested practice problems with no grading or feedback.

Economics of the SEI Transition Costs

The purpose of the SEI was to carry out a realistic experiment to see if it was possible to achieve widespread change, not to find a model that would minimize the costs of such change.

Table 5.5. Total cost and annual value experienced by UBC

Cost of UBC SEI	$9 million total
Value of credit hours impacted (@ $500 per credit hour)	$70 million per year

For the benefit of other institutions that may consider a similar effort, we have done a simple analysis of the economics of the current model and find it is more attractive than we expected (see Table 5.5). Focusing only on UBC, where the data are cleanest, there are now about 140,000 credit hours a year being taught in a significantly improved form. Because of the UBC funding model, it is difficult to determine the actual cost-per-credit hour, but looking at cost-per-credit-hour data from a number of comparable large public U.S. institutions where it is available, $500 per credit hour is at the low end of the cost range. If we use $500 per credit hour, as of the 2013–2014 academic year the UBC SEI was providing significant enhancement to the value of $70 million worth of credit hours each year. This was accomplished at a total cost of about $9 million as of 2014. Our own measures of improved learning and results from the broader literature on science education research would indicate the transformed courses are likely providing 10–30 percent greater learning. That would equate to an effective increase in the value of those credit hours of between $7 million and $21 million per year. As all current indications are that those improvements in the courses are continuing after the SEI is no longer supporting them, this annual benefit will be continuing for the indefinite future with no additional cost.

Of course, I realize that university budgets are based only on the number of students that enroll, not on the amount of learning that takes place, but this admittedly simple analysis suggests that if one did look at the value of the increases in learning that have been achieved, the SEI model in its current form has been a very a good investment by UBC.

Private Fund-Raising for SEI-Like Activities

There is a reason that the SEI programs were nearly entirely funded from within the universities. There are some unique challenges in raising money from outside the university for such efforts, and these are noted as a warning for anyone considering trying to replicate such an effort.

Despite a large amount of effort in the two years before the SEI began, and for some years after, I had no success in getting funding for an SEI program from existing external grant programs, public or private. Here are some of the likely reasons for this failure.

First, appealing to a donor to support efforts by the university to teach well is perceived to be simply offering the university and its faculty a special bribe to do the job for which they are already getting paid for.

Second, much of the contributions to universities come from satisfied alumni. But satisfied alumni are not going to see changing undergraduate teaching as a high priority, because they were happy with their experience. A dissatisfied alumnus, or a student who withdrew from the university and was not happy with the quality of teaching, is not likely to want to contribute.

Third, most large private donors and foundations have specific priorities that they want to support. The SEIs are quite unusual and do not align well with those priorities. Also, national priorities and attention in education are almost entirely focused on K-12, although there has been a slight shift in recent years.

Fourth, because this effort is quite different from the usual things universities raise money for, the university development offices struggled with how to sell it. Though some potential donors expressed interest to me after initial meetings, the development team often failed to follow up on this interest, probably because of uncertainty as to how to frame a suitable discussion and request.

UBC was eventually successful at raising substantial private gifts to support the SEI, and I am aware of other institutions recently obtaining private donations to carry out SEI like programs. In all of those cases, the SEI was presented with similar arguments used by a high-tech entrepreneur pursuing venture capital: *"There is something new and exciting here, namely, the recent research on learning and its successful demonstration of dramatically improved results in college classrooms. These new, more effective teaching methods are the wave of the future, but they need some start-up funding to get established and into the mainstream. So, modest amounts of one-time funding now can get them over the initial start-up hump and lead to dramatic long-term results."*