III. Educational programs

A. Educational philosophy

Our success in educational endeavors is attested to by our receipt of an inaugural University of Washington Brotman Award for Instructional Excellence – essentially a departmental Distinguished Teaching Award, created in 1999 through a gift from Regent Jeffrey Brotman and his wife Susan.

Dean of Engineering Denice D. Denton nominated our department for this award. Her nomination letter is included as Appendix I. When we became Finalists for the award we were asked to submit a short "Reflective Statement." That statement neatly describes our educational philosophy, and is included verbatim here:

Brotman Award "Reflective Statement"

Ed Lazowska, Professor and Chair
Department of Computer Science & Engineering
Spring 1999

Computer Science & Engineering is honored to have been nominated by Dean Denton for the inaugural Brotman Awards for Instructional Excellence.

CSE's educational efforts are shaped by a four-point philosophy:

- We believe that universities are, first and foremost, educational institutions, and that faculty members are, first and foremost, educators. Students are the "product" of the university and its faculty, in both senses of the word: they are the "output," but more importantly they are the "multiplier" that provides leverage for every faculty member. There are other ways to obtain leverage – one can, for example, conduct research without student involvement. But if you seek your primary leverage in some way other than by educating students, then you will be most effective in some other environment.
- We believe that a *research* university is a unique institution that can provide a unique undergraduate education – an education in which bright and committed students are brought to the very forefront of knowledge, closely mentored by faculty who are (with their students) working to redefine that forefront. More importantly, we believe that a research university *must* provide this kind of education, because no other institution can, and because any other kind of education can be provided better and/or cheaper elsewhere. We believe in differentiation: there is something that only the University of Washington and its peers can do, and we must focus on it. "If we're not striving to seamlessly integrate research and education, we're screwing up."
- We believe in taking a holistic view. Today's K-12 students are tomorrow's UW students; we must give them the tools to succeed. The citizens of Washington and their elected representatives pay the bills; they are entitled to a clear explanation of what we are trying to accomplish. The high-technology companies in our region, and our colleagues elsewhere at the University of Washington, represent enormous competitive advantages for us (and we for them); we must reach out in many ways. The future of the University of Washington is inextricably linked to the future of our region; creating a climate conducive to a 21st-century technology-based economy serves everyone's interests. Finally, special responsibilities fall to computer science programs as we approach the millenium, because of the role that computer

science is playing in transforming all aspects of our lives; we must rise to these responsibilities.

- Finally, we believe that the University of Washington's highly capable students, staff, and faculty will respond to encouragement and example, striving for excellence in response to high expectations.

Our educational efforts and approaches follow directly from these principles. We strive to create the best possible educational experience for our students – one that benefits from, *and that benefits*, our position as a top-ten research program. We invest in our introductory courses because knowledge of computing is fundamental to success in the modern world, and because these courses are the "attraction waters" for our major. We aggressively recruit, advise, tutor, and mentor students, because we want a diverse collection of the University of Washington's finest students in our program, and we want these students to succeed. We encourage our undergraduates to work alongside faculty and graduate students as TAs, because this benefits both the students taking the courses and the students who TA them, and creates a "learning community" that extends from the youngest student to the oldest faculty member. We similarly encourage our undergraduates to work alongside faculty and graduate students as RAs, because this is one of many ways in which these students benefit from the unique type of education that only a research university can provide. We facilitate co-op and internship employment because, if properly integrated, it teaches the students things that are complementary to those they learn in our program. We constantly introduce new "Capstone Design Courses" (many of which are interdisciplinary) because our field is advancing at a remarkable pace, and because these courses provide an unparalleled opportunity for students to synthesize what they have learned throughout their studies. We employ a wide range of "carrots" to encourage outstanding teaching, because encouragement and example work best: a departmental TA award, a departmental faculty teaching award, nomination of faculty and students for University and national recognition, quarterly student evaluations and annual peer evaluations for all faculty, quarterly circulation of a histogram of student evaluations for faculty and for TAs, and more. We invest aggressively in educational technology because it allows us to reach a broad audience of students and citizens, and because we believe that ultimately it will change the nature of education, allowing faculty members to spend more of their time doing the things that only they can do.

That, in fact, is our overriding objective: to do the things that only we can do, and to do them as well as they can be done.

B. Overview

We have a wide range of educational programs – some clearly "core" and some more peripheral. A fairly complete accounting:

Introductory curriculum

CSE 142 (http://www.cs.washington.edu/education/courses/142/) and CSE 143 (http://www.cs.washington.edu/education/courses/143/) are a University-wide service course sequence in programming. CSE 142 enrolls 450-550 students per quarter during the academic year; CSE 143 enrolls roughly half that number. (During Summer Quarter, each course has roughly half its academic year quarter enrollment – total annual enrollment is greater than 2500 and climbing.) These courses are well-designed, well-taught, and well-received. Because our undergraduate major programs have enrollment caps, these are not "filter courses" – they are, instead, our "attraction waters," and we put a lot of energy into them. *Adequate laboratory space is a crisis for these courses.*

We have recently introduced CSE 100, "*Fluency with Information Technology*" (http://www.cs.washington.edu/education/courses/100/). This is a course for "the other half" of UW's students – those who need fluency but not hard-core programming. Professor Larry Snyder designed and introduced this course based upon his NRC work. Our goal is to have this become the new School of Information's introductory course, with CSE investing just enough energy to ensure that the curriculum does not lose the essential "technology" aspects described in Snyder's NRC *Fluency* report.

A curious characteristic of higher education policy in Washington State is that many students who desire a Bachelors degree are steered to a Community College for their first two years. As a result, we in CSE devote considerable energy to enabling the state's Community Colleges to teach high-quality offerings of our introductory courses. Tutored Video Instruction is one approach that we have employed (http://www.cs.washington.edu/education/TVI/). (Having a complete web-based record of each course, including integrated audio/video/transparencies, is a major benefit to UW students too.)

Undergraduate major programs

The department has two undergraduate major programs: a Computer Science degree offered through the College of Arts & Sciences, and an ABET-accredited Computer Engineering degree offered through the College of Engineering. Together, these programs by next year will enroll about 430 students (sophomores, juniors, and seniors) and graduate approximately 160 students each year. (We currently are increasing our capacity from 320 registered students and 120 graduates per year.)

Because the demand for our undergraduate major programs exceeds the capacity (due to laboratory, faculty, staff, and TA resources), students are admitted on a competitive basis upon completion of prerequisite courses. Our undergraduates are wonderfully strong, classes are small, and interaction with the faculty is high. Undergraduate participation in research is common. Intensive "Capstone Design Courses" are a hallmark of our undergraduate major programs. In the course of their education, roughly two-thirds of our undergraduates participate in co-ops or internships.

These programs will be described in detail subsequently.

Alternatives at the undergraduate level

Even given infinite resources, "open enrollment" for undergraduates would be problematic. Although the University of Washington has an "elitist" reputation within the state, it is in fact quite non-selective at the undergraduate level compared to other major research universities. For example, at the 8 campuses that comprise the University of California system, an average of 95% of the freshmen graduated in the top 10% of their high school classes; at the University of Washington, only 37% achieved this standard! This enormous disparity arises from a second curious characteristic of higher education policy in Washington State: two-thirds of the students who earn Bachelors degrees in our state attend research universities, whereas in California and Michigan (just to cite two examples) that fraction is only 1/3.

We believe that our state is best served by a diversity of educational opportunities. We believe that our unique role is to produce exceedingly highly-leveraged "hard core" computer scientists and computer engineers who will lead our region and nation in the future. Thus, our goal in CSE is to have sufficient capacity in our own programs for every student who is

comparable to those at our peer institutions – who is prepared to benefit fully from the education that a top department at a top research university is able to provide if it's doing its job right – and to do an extraordinary job of educating these students. It is also our commitment to help ensure that there are viable alternatives for other students – alternatives on the UW Seattle campus, at the UW branch campuses, and throughout the state – that meet their needs, and the needs of the region.

On the UW campus, existing programs provide alternatives for most students who we are unable to accommodate. For example, during the most recent round of admissions, 60 students who we could not accommodate (two-thirds of those who chose to enter a major rather than remaining a pre-major for an additional quarter) enrolled in Electrical Engineering.

For other students, we helped create the Applied and Computational Mathematical Sciences program (http://www.ms.washington.edu/acms/) with our colleagues from Applied Mathematics, Mathematics, and Statistics. As of Spring Quarter 1999, there were 114 ACMS majors, three-quarters of whom had selected the "computer science" track (which is called "Discrete Mathematics") – a track for which we teach a number of upper-division courses that are best described as "minor" courses.

We have partnered with the new UW branch campuses to create Computing & Software Systems programs at UW-Bothell (http://www.bothell.washington.edu/prospect/css/) and UW-Tacoma (http://www.tacoma.washington.edu/css/). The UW-Bothell C&SS program has been in operation for several years, and is graduating 80 students per year. The UW-Tacoma program began this fall, and should quickly ramp up.

Self-Sustaining Programs

We have a long-standing partnership with UW Educational Outreach that offers a variety of self-sustaining programs.

Most visible is a suite of 25 Extension "Certificate Programs" that we oversee (http://www.extension.washington.edu/extinfo/certprog.htm#computing), each consisting of an integrated sequence of courses. The Certificate Programs have titles such as "C Programming," "C++ Programming," "Java Programming," "Data Communications," and "Software Product Management." The students are industry professionals or individuals desiring to enter the industry; the courses have a technical depth well beyond what a community college is equipped to offer; the instructors are typically industry professionals who are carefully vetted by CSE and Educational Outreach (we also control the curriculum). During the 1998-99 year, these programs generated more than 3,500 course enrollments, and granted more than 600 certificates (representing the completion of an integrated multi-course sequence) – very significant impact.

We have two new initiatives underway with Educational Outreach. The first (supported in part by a grant from the U.S. Department of Education) is a partnership with Prentice Hall, the World Organization of Webmasters, and the Public Broadcasting System to address the acute lack of skilled internet professionals. We are jointly designing, implementing, and evaluating four Certificate Programs and accompanying materials to be delivered online, on-site, and in video formats, providing the first comprehensive series of programs about the internet that will be offered in any place and at any time. We are also developing national standardized assessments that will be mapped to the competencies and learning outcomes of the four Certificate Programs, and we will scale the program to a national audience through delivery via

the web and CD-ROM, televised and internet broadcasts, licensing agreements, and self-directed tutorials.

The second new initiative is an effort joint with Educational Outreach and UW-Bothell (with UW-Tacoma likely to join) intended to create carefully articulated self-sustaining credit-based Certificate Programs that collectively lead to a UW degree. The Introductory Computer Programming Certificate Program, already in its second quarter, will be following by one or two more Certificate Programs comprised of UW-Seattle courses, with a set of UW-Bothell Certificate Programs to follow; after completing the Certificate Programs, a student will have met the requirements for a UW-Bothell C&SS degree.

Professional Masters Program

This program, introduced in Autumn 1996, will be described in detail subsequently. Its students are forefront employees in the region's software industry – roughly 120 students from roughly 35 companies, with between 1 and 25 years of professional experience. This program broke new ground for the University of Washington in a number of respects.

Full-time graduate program

Our full-time graduate program enrolls roughly 150 students, the vast majority of whom are full-time Ph.D. students. (In truth, we do not actively recruit full-time Masters students; our admissions process is blind to the "degree box" that applicants check, with "potential for forefront research" being by far the dominant selection criterion.) This program will be described in detail subsequently.

C. Bachelors programs

Overview

We offer two undergraduate major programs: a B.S. in Computer Science through the College of Arts & Sciences, and an ABET-accredited B.S. in Computer Engineering through the College of Engineering. By design, these programs are more similar than they are different – each has an "engineering orientation," they share many courses, and students from both programs participate in our hallmark Capstone Design Courses. We devote an enormous amount of energy to these programs, which attract some of the finest students at the University of Washington and which are recognized regionally and nationally for producing outstanding students who attend top graduate schools and join forefront companies in all segments of the computing industry.

Admission and student demand

At the University of Washington, it is traditional for students to apply to majors at the end of their sophomore year – an unfortunate "delayed binding" related to Washington's higher education policy that anticipates a large number of community college transfers. Popular majors (including *every* major in the College of Engineering) have capacities that fall short of meeting demand, with the result that the departmental admission processes are competitive (in varying degrees).

In the past ten years, we have doubled the number of undergraduates that we admit annually, and we have almost tripled our total undergraduate enrollment. Demand continues to exceed capacity by a significant margin, however, and our majors are outstanding and comparable to

those in the best programs nationally. (See Appendix J for recent application / admission / matriculation data, and comparison to other UW Engineering programs.) It is our commitment to provide these outstanding students the outstanding education they deserve – a mission that we believe best serves the needs of the State of Washington.

The doubling in annual admissions has occurred through the addition of the Computer Engineering program in 1989 (it had been initiated a year or two earlier in EE and was transferred to our department when we were moved from Arts & Sciences to Engineering), our immediate expansion of the program from 20 new students per year to 40, and – just this fall – our further expansion of the program from 40 new students per year to 80, matching the size of our Computer Science program. (Note that we have never taken a rigid approach to the relative sizes of the two programs. Also note that having a program in Arts & Sciences is an enormous advantage for us; it turns out that not every outstanding student at UW is a pre-engineer!)

The tripling in total undergraduate enrollment – the fact that growth in enrollment exceeds growth in admission – is due to conscious steps that we have taken to encourage students to join our major earlier, and to participate in co-ops that slightly extend their stay.

We have spearheaded several initiatives to encourage students to join our major earlier. We believe that this benefits the students intellectually (allowing them to construct balanced schedules with major and non-major courses in all four years) and psychologically (increasing the sense of community they feel). Our initiatives have included decreasing the pre-requisites required for admission; driving the creation of an early admission process in the College of Engineering (with a further reduction in requirements); and, most recently, creating a new "early decision" program through which extraordinary high school seniors are admitted directly into the major (an innovation that will soon be emulated throughout the University).

We also have consciously tried to increase the number of students who participate in co-op programs and other industry internships. Currently, roughly two-thirds of our undergraduates participate in co-ops or internships. We strongly encourage this participation not only so that students can sample and learn from industry working environments, but also because they bring back new perspectives to the classroom and we observe a much higher motivation and direction in their studies. This does have the effect of increasing students' time to graduation, but with a strong benefit. (We also have aggressively increased undergraduate participation as Teaching Assistants and as Research Assistants – tremendously positive experiences that do not affect time-in-program.)

Curricular evolution

The principal philosophies guiding the evolution of our curriculum have been to ensure that students in both our programs receive a common and solid foundation in the discipline; to provide students with maximum flexibility in their senior-level and elective courses; and to rationalize pre-requisites both in subject and number. Achieving these ends required initiating a re-thinking of College of Engineering requirements that led to a decrease in the number of credits needed for Engineering degrees from 192 to 180 (and simultaneous institution of early admission to majors); and achieving departmental ownership of what were previously College-wide courses (these courses were labeled ENGR; with no department having direct responsibility, they greatly suffered from lack of attention). Both of these initiatives, led by our department, have had far-reaching effects across the College.

All of our students – whether Computer Science or Computer Engineering – now share a common core of sophomore/junior-level courses in the department, and almost identical pre-requisite requirements for admission. Our admission process can be almost blind to the program to which the student is applying (the difference has been reduced to only two pre-requisite courses). Our students can move between programs as they clarify their interests and needs over their time in the department. Reducing the rigidity of the Computer Engineering program has encouraged students to select it who otherwise would have selected Computer Science purely for its flexibility rather than for its orientation.

This year, with the expansion of our Computer Engineering program, we seized the opportunity to restructure our undergraduate offerings holistically. Rather than merely doubling the capacity of Computer Engineering, we created two "tracks" or "options." Computer Engineering students can now choose between a traditional, hardware-oriented program of study (a refinement of our program prior to the expansion), or a new one with an emphasis on embedded software (that has a very different mix of senior-level courses, two of which are new). Within each of these options we have also relaxed requirements so that students have more choices among their senior year courses. For example, each Computer Engineering option has two possible Capstone Design Courses and students are free to choose which they will complete. Viewed as a whole, the Computer Science major and the two Computer Engineering options constitute a broad spectrum, with a great deal of senior-year and elective flexibility. This allows students to choose between the programs late in their studies (subject, of course, to fulfilling Colleges requirements).

Beyond our Computer Science and Computer Engineering major programs, we have seen a steady enrollment increase in our non-majors sequence. This is due to the increasing popularity of the Discrete Mathematics and Algorithms option of the Applied and Computational Mathematical Sciences program – which we administer jointly with Mathematics, Applied Mathematics and Statistics – and to the increasing demand from students in the Computing option of the Electrical Engineering major. We have expanded our non-majors course offerings to serve these students.

Other curricular developments include the reinvigoration of our introductory programming courses, which now serve more than 2500 students per year (up by a factor of five in the past decade); the creation of a new *Fluency in Information Technology* course (joint with the new School of Information) derived from Larry Snyder's NRC study; and the initiation of a seminar on ethical issues and societal impact of information technology.

Our introductory courses are first and foremost service courses, but they also serve as our "attraction waters." Students in these courses benefit from the fact that our majors are capped, because there is no hint of a "filter course" mentality in our approach. These courses have an increasingly diverse population. We have instituted low- and high-preparation recitation sections to these courses to maximize the chances that all students have a positive experience. Hotshots get to mix it up with other students experienced in programming, while not intimidating students new to the subject. Students with little or no background in computing can be assured increased attention to their needs in a more nurturing environment.

The new "*FITness*" course provides a much-needed resource for students new to computers. We envision the rapid expansion of this course (which will drive the faculty count in the School

of Information and also serve to attract majors to their new Bachelors program), and we also see it as a model for high school curricula.

Our new ethics seminar is a (late) step in increasing awareness of the impact of information technology in all spheres of life. Business, law, public policy, and privacy are a small sample of the areas with which many of our graduates will have to interact in their careers. We plan to introduce a new senior-year elective as well as introducing modules into several of our existing courses to tackle these issues. This approach will be particularly attractive in our senior project-oriented courses where students can discuss the implications of their projects and the effects that products embodying similar ideas may have on society.

Taken together, these developments attest to the increasing centrality of our discipline, and to the need to adjust to the ever more diverse students who are drawn to it.

Curricular innovation

The principal innovations in our curriculum over the past ten years have occurred in our senior-level courses. We now have a set of six "Capstone Design Courses" in areas as diverse as embedded system design, hardware design, computer animation, software systems, integrated circuits, and computer telephony. This year we are offering a new Capstone in Internet technologies; we plan another next year in human-computer interfaces.

Ideally, Capstone Design Courses have students apply the lessons they have learned in many of their previous courses in a multi-disciplinary, team-oriented, integrative design experience. Our Capstone Design Courses have been a great success in this regard. A case in point is the computer animation course. Majors from art, music, architecture, and CSE work together to develop and produce a short animated film. The students learn how to communicate with others trained in very different disciplines and organize into groups around the major steps in producing the animation such as modeling, lighting, shading, and sound/music. Over the years, several of these animated shorts have won awards in prestigious international festivals. In the embedded systems Capstone, students have prototyped innovative devices for home automation, portable computing, and robotics. Example recent projects include a wireless-connected personal digital assistant that provides an interface to Seattle's Metro bus system so that a user can see the real-time position of busses on a map of the region of interest ("taking the wait out of public transportation"); the conversion of a factory automation robot into a checkers player that actually moved pieces around and on/off a physical board and played against a human opponent; and the creation of web-based services to provide up-to-the-minute estimates of travel time, taking into account actual traffic conditions (including automatically warning the user when s/he needs to leave earlier to compensate for congestion). Each year, we produce videos highlighting the student achievements in our Capstone Design Courses. These videos, which we distribute widely on CD-ROM, have been immensely useful in our recruitment efforts (we carpet-bomb high schools with them) and in giving our students an excellent addition to their portfolios. (See Appendix O for last year's Capstone Design Course CD-ROM.)

Most recently, we have moved to align our Capstone Design Courses with our technical writing course requirement. Students can concurrently enroll in a Capstone course and a technical writing course and use their projects as the motivation for their writing assignments. The benefit to the Capstone course is that students now actually have an opportunity to refine their project proposals, reports, and presentations. The quality of the documentation is improving dramatically and students gain efficiency. The benefit for the technical writing instructor is that

students are writing about a subject that they care about and are more motivated by the linkage between the courses.

In summary, our undergraduate curriculum is now tiered such that there is a common core of sophomore/junior-level courses on which all of our senior-level courses are layered. Capstone Design Courses reside above some of the senior-level courses providing integrative design experiences in myriad areas. Class sizes are progressively smaller as students move through the program, ranging from 60 in some of our common core courses down to 15 or 20 in many of our Capstone courses. We strive to minimize the length of pre-requisite chains, to increase flexibility for students and in recognition of the fact that we "own" our majors for fewer years than would be desirable. We strive to reduce the overhead of introducing new Capstone Design Courses, and of introducing or shifting material in the curriculum. Topics previously in Capstone courses migrate into senior-level courses and even further. Capstone courses provide a key motivation for curricular updates – we introduce in lower-level "core" courses the material needed to achieve the design and implementation of state-of-the-art software and hardware artifacts.

Extra-curricular elements

Our department prides itself for providing diverse opportunities for our students. We seek not only to ensure that they have a solid intellectual foundation, but also that they have the opportunity to experience research, teaching, and working in our field.

We strongly encourage industry employment during students' time in our program. At least two-thirds of our majors complete a co-op experience or a summer internship. Often the experience lasts more than 3 months and in some cases up to a year. We work hard to ensure that these experiences are positive by strongly involving our Industrial Affiliates in recruiting our undergraduates for these positions. Thus, our students are likely to be employed by those who understand the role of employment in complementing our educational program.

Outside employment is not the only option, however. We also encourage students to become involved in the academic enterprise, both in research and in teaching. Nearly one-third of our students are engaged during their undergraduate years in independent study or as research assistants working alongside graduate students, postdocs, and faculty. Many of our undergraduates become co-authors on research papers (in one recent year, four UW SIGGRAPH papers had undergraduate co-authors). Our undergraduates also serve as teaching assistants for many of our courses, and an undergraduate category has been added to our highly-prized Bob Bandes Teaching Award for teaching assistants. It is particularly effective to use senior undergraduates as TAs in Capstone Design Courses or other courses with significant laboratory components. They have taken the course themselves and are familiar with the laboratory environment and can be effective with lower overhead than a graduate student unfamiliar with software, hardware, and/or equipment. The students who TA find the experience immensely fulfilling. Teaching and research experiences help guide some of our students toward graduate school as they begin to taste the excitement of an academic career.

To build a strong sense of community, we rely heavily on student-run organizations, most particularly our student ACM chapter. The leadership of this group acts as a liaison between the department and its students. The ACM chapter provides a focal point not only for industry contacts and recruiting, but also for volunteer mentoring of new students, awards for teaching excellence (an idea that we shamelessly plagiarized from the University of Virginia), inter-university contests, and social activities that help make the department cohesive. In addition, the

Chair meets with undergraduates monthly at a pizza lunch; feedback from these sessions has led to a number of adjustments in facilities (providing increased lab space for independent projects) and curriculum (adjusting out-of-department requirements).

Program management

Our undergraduate programs are managed by an undergraduate faculty advisor who oversees two staff advisors, their assistant, and a fraction of a database technologist. The department's undergraduate advising unit has four principal functions: recruit the best possible students into our major programs, help them succeed in their goals, ensure that they graduate in a timely manner, and help other students find suitable options.

Our recruiting efforts have escalated dramatically in the past few years as we seek to ensure that the top students in the University, state and region are applying to our department, and to increase the diversity of our student population. We have taken an active role in organizing freshman interest groups (FIGs) for students interested in computing majors – the first FIGs in Engineering. As mentioned earlier, we have initiated what is becoming a university-wide initiative to admit extraordinary high school seniors directly into majors. Our CD-ROMs have been a huge success. Through a donation from alumnus Jeremy Jaech (co-founder of Aldus and Visio) and his wife, we have been able to hire an Outreach Coordinator whose special focus is the recruitment and success of students from under-represented groups. More broadly, we have instituted an extensive mentoring and tutoring program. Students having difficulty in our courses are identified quickly and early so that we can connect them with the resources to help them get over some of the hurdles they encounter. We have implemented a complete database that includes each student's complete record so that we can track how well s/he is doing efficiently and thoroughly, dramatically reducing the number of students who fall through the cracks.

Summary and future plans

We invest enormous energy in undergraduate education, and are innovators in education at the University of Washington. This is evident in the preceding material, and is attested to by our receipt of an inaugural UW Brotman Award for Instructional Excellence (essentially a departmental Distinguished Teaching Award) last year. We are grateful for the consistent encouragement and support we have received from the Office of Undergraduate Education, and of course from the students we serve.

Enrollment pressure and outreach pressure are the two major external forces acting upon us. It is our view that we best serve the State of Washington by providing outstanding students with an outstanding education, and by providing University-wide and statewide leadership in creating a broad range of alternatives for students whose needs are not best served by the programs that we ourselves can offer. The enrollment graphs at the end of Section III show clearly how responsive we have been. At the core, though, there is a unique type of undergraduate education that a research university can provide, and this must be our focus. If we don't, who will?

Of the prospective majors who we are unable to accommodate, nearly two-thirds become Electrical Engineering majors. Many of the rest either choose other Engineering majors, or the Applied and Computational Mathematical Sciences program (which is not capped). In the future, we expect an increasing number of these students to choose the Computing & Software Systems majors at UW-Bothell or UW-Tacoma. We must continue to work with our colleagues within the

University and at other institutions to ensure the existence of a broad range of alternatives that meet a broad range of needs.

Future developments for our majors include the continued introduction of new Capstone experiences, and the formalization of a curricular revision process that integrates new material (often stimulated by these Capstone courses) into the base curriculum. We see this as an excellent mechanism for continual renewal and relevancy.

D. Professional Masters program

Overview

The Professional Masters Program (PMP) was created in Autumn 1996 to satisfy a regional need for advanced education of professionals working in the information technology industry. The educational goal of the program is to provide the students a deeper background in computer science and engineering to allow career advancement, as opposed to enabling a career change or preparation for graduate school. Other goals included creating interactions with a different set of students, increasing interactions with industry, being responsive to regional workforce issues, moving us ahead in educational technology, and generating additional resources for the department (the PMP is a state-funded program that brought us 5 faculty, 5.5 staff, and 7.5 TAs).

In any program for students working full-time, accessibility is essential. All PMP courses are offered in the evenings and some classes are offered via distance education. The distance learning courses utilize integrated web and videoconferencing technologies between sites at UW, Microsoft (Redmond) and Intel (Dupont). Since PMP students are less tied to the academic schedule than full-time students, courses are also offered summer quarter. In addition, both degree structure and individual courses have been designed with the working students in mind. The degree requirements are coursework-only with no thesis or projects outside of classes. To allow flexibility for students, there is no prerequisite structure between the courses, nor are there course distribution requirements. The courses generally have the same coverage and rigor as courses in the full-time graduate program, but projects are scaled back since the assumption is that students in the program spend their days doing projects.

The program was funded at 40 FTE. Approximately 50 students are admitted per year. Current enrollment is just under 120 students. A 40 FTE Master's program has the potential of producing 30 degrees per year. (By UW formula, 40 FTE is equivalent to 400 student credit hours per quarter, or 1200 student credit hours per year. Since a Master's degree is 40 credits, there are potentially 30 degrees per year, assuming 100% graduation.) Currently, the program is slightly overenrolled with respect to the FTE number. Application, admission, matriculation, and enrollment information is available in Appendix A ("Graduate Student Statistical Summary (from the Graduate School)") and in Appendix K ("Professional Masters Program Application / Admission / Matriculation / Enrollment").

The prototypical student entering the program has a strong degree in Computer Science or Computer Engineering and five years of work experience at a leadership information technology company. The admission guidelines allow for a multitude of backgrounds. Approximately 65% of admitted PMP students have Computer Science or Computer Engineering degrees and most of the remaining have degrees in the sciences or engineering. The professional experience of students entering the program ranges from 1 to 25 years. PMP students represent a diverse collection of companies, currently drawing from 34 firms. Microsoft has substantially more

students in the program (over 40% of the total) than any other company. Aside from Microsoft, two other companies considered key to the program due to their major presence and contribution to the community are Boeing and Intel.

Evaluation

The success of the PMP in fulfilling its objectives has been positively reflected statistically, through the praise of the CSE faculty, and most importantly, through the achievement and satisfaction of PMP students.

The numbers are solid at every juncture. The application rate and strength of applicants was high enough to achieve steady state after only the program's third year. The progression of the students through the program is also steady: there are currently 40 graduates of the program, with an additional 15 expected at the end of Winter Quarter 2000, and time from program entry to degree for the graduates to date has averaged 2.3 years. (Factoring in those in the program yet to graduate may raise this slightly over the 2.5 year target.) The attrition rate of PMP students is low: only 16% of the students admitted in 96-97 and 97-98 academic years have left the program without a degree.

Overall the program is attracting strong and well-rounded students. The students who enroll have excellent undergraduate GPAs (a 3.6 average for all students) and GREs, and also have solid work experience. The GRE scores for students joining the PMP in Autumn 1999 were virtually identical to the scores for students joining the full-time program in the same quarter: for the 26 students joining the PMP the GRE averages were 636 Verbal, 763 Quantitative, and 736 Analytical, while for the 42 students joining the full-time program the averages were 631 Verbal, 775 Quantitative, and 724 Analytical. As previously noted, the students are also diverse in the companies they represent and in their technical areas of interest. This is very important for the program, since it is essential that the PMP does not target just a single sub-area of computer science or portion of the industry.

Students generally appear to be very happy with the program. Direct feedback to instructors and advising staff has consistently reinforced that the courses and the program are valuable and challenging.

There has been a clear improvement in the technical quality of our distance learning offerings. Some of this is due to improvements in technology, and some to increasing department experience. All distance lectures are available on-line for download at http://www.cs.washington.edu/education/dl/course_index.html. A significant number of Eastside students rely on distance courses. There are even a few students who view the lectures at their desktops instead of in the classroom, although this practice is discouraged. An additional component of the PMP is participation in the CSE Colloquium, which is available on the web, either streamed live or archived for on-demand viewing.

There is room for improvement in the distance courses. There are still technology-related issues such as maintaining adequate audio quality to support interaction, and the need for better gizmos of various kinds. There have been difficulties with the remote sites – technical glitches that could have been avoided if someone at the remote site had taken responsibility. The program has not succeeded in finding someone at Microsoft with sufficient clout, interest, influence or ability to take ownership of their end. There is a huge potential for collaboration with Microsoft

on educational technology and the PMP, but despite persistent efforts on our part this has yet to happen.

Another difficulty with distance education is faculty resistance. Teaching a distance course is different from teaching a conventional course, and there are legitimate concerns that faculty have raised about teaching distance courses. These include a reduced level of interaction with students, a constrained teaching style, and increased workload due to the use of web-based transparencies. A distance instructor has been supplied every quarter, although finding a willing instructor has complicated the scheduling, and some arm-twisting is usually required.

The bottom line is strongly positive. We close this section with an anecdote: excerpts from email sent spontaneously by Professor Brian Curless, who taught Computer Graphics in the PMP during Autumn 1999:

> I was really impressed by a lot of the PMP students (I taught the graphics course last quarter).
>
> I was also amazed to find that the star student in my class is a "tester" in the Office group. Clearly under-utilized at MS. I've asked David/Michael to see if they can find something better for him.
>
> In fact, having taught undergrad, grad, and PMP, I would say that the PMP class was the most fun so far. We laughed a lot during lecture, and they worked hard and learned tons. I've mentioned this to a number of faculty. Of course, I hope Zoran doesn't take it to heart -- I want to teach it again in a couple years!
>
> I made a 4.54 overall on the PMP course evals - I'm psyched!

(The student noted in the second paragraph is a tremendously bright guy who had been relegated to a testing job at Microsoft because his Berkeley Bachelors degree was in Music and Mathematics. "David/Michael" are Salesin and Cohen, who we expect will draft this student into the Microsoft Research graphics group.)

Future issues for the PMP

While it is safe to say the PMP has established itself as a successful program in the department, there are several issues that will require continual attention. The PMP could accommodate more students without a substantial change in the quality of student that it attracts. For example, growth of the program from 40 FTE to 50 FTE (given appropriate resources) would be easy to attain.

There are opportunities for an intellectual broadening of the PMP by introducing multidisciplinary courses. The program is already broad within CSE. An example of a course that has been talked about, but not initiated, is a course in software project management, which would combine both management and software engineering. This would be a valuable course for students who started their careers as developers but have acquired management responsibilities as they have advanced. Another business-related course that could generate interest and value would be a course related to high-tech strategy. There are also many opportunities to expand the program in the direction of Electrical Engineering or the School of Library and Information Science.

A strategy that was taken in developing the PMP was to keep it separate from the full-time program. This was probably a correct strategy while the program was establishing itself, but now that it is a mature program, it might be a good idea to reevaluate this approach. It could be possible to have courses play multiple roles in the department to maximize resource efficiency.

Cross-enrollment between PMP courses and full-time graduate courses to this point has been relatively low, but by adding attractive options for full-time students and by playing to the increasing flexibility in the high-tech workplace, additional crossover is possible.

Staffing of courses is a problem for the department as a whole. Many of the PMP offerings are in areas where there is already a shortage of faculty. The program has relied on a number of outside instructors to teach courses. This has included the opportunistic use of visitors as well as experts from industry such as Phil Bernstein (an internationally recognized expert in databases and transaction processing who works at Microsoft Research). The staffing of PMP summer courses is a particular challenge.

Recruitment of students and general company relations are ongoing areas of focus for the program. As the program matures, the graduates are expected to be the program's number one recruiters, but in the ever-changing high-tech marketplace it will still be necessary to continue to pay attention to employment trends, maintain good relations with established corporate partners, actively market the program to the information technology community, and seek new companies to send students to the program.

The PMP addresses a particular segment of the demand for professional education. There are many needs that the PMP was not intended to meet. For example, there is a very high demand for a "Professional Bachelor's Program," which would allow people with other backgrounds to make a career change into the computing industry. This is outside of the scope of the program. In the early days of the program, the PMP denied admission to a large number of applicants who were actually seeking an undergraduate degree in computing offered in an accessible manner.

E. Full-time graduate program

Overview

Our full-time graduate program enrolls roughly 150 students, the majority of whom are Ph.D. students. In truth, we do not actively recruit full-time Masters students (as opposed to PMP students); our admissions process is blind to the "degree box" that applicants check, with "potential for forefront research" being by far the dominant selection criterion.

Admission, support, and demographics

Recently we have tended to receive roughly 650 completed applications per year. We admit roughly 15% of the students who apply, and we enroll roughly 1/3 of those we admit. (We lose significant numbers of students only to MIT, Stanford, Berkeley, and CMU – but of course we win some too.) The average GRE scores of matriculants, averaged over several recent years, tend to be about 650 Verbal, 775 Quantitative, and 750 Analytical.

We promise incoming students funding for their first 3 years of study, although as a practical matter no student goes unfunded for his or her remaining years of study. Among all students in the program, roughly 20% are supported on fellowships, 50% by research assistantships, and 30% by teaching assistantships. (The Graduate School data on student funding in Appendix A is technically correct but misleading; see our own Appendix L for more meaningful information.)

Roughly 1/3 of our student body (roughly 50 of roughly 150 students) consists of international students. Roughly 15% of our student body (currently 23 students) consists of women. Roughly 5% of our student body (currently 6 students) consists of minority students (African American, Hispanic American, or Native American).

This information is detailed in Appendix A ("Graduate Student Statistical Summary (from the Graduate School)") and in Appendix L ("Full-Time Graduate Program Application / Admission / Matriculation / Enrollment / Support / Demographics").

Outcomes

In connection with this Self Study we examined the records of the 423 students who entered our full-time graduate program between Autumn 1985 and Autumn 1998 inclusive. Of these students, 307 have left the department and 116 are still enrolled. Some summary information:

- Of the 307 departed students 71% declared themselves to be pursuing a Ph.D. at the time they applied; 29% declared themselves to be pursuing a Masters.
- Of the 218 students who declared themselves to be pursuing a Ph.D. at the time they applied, 48% received a Ph.D., 39% received a terminal Masters degree, and 13% left without obtaining a degree.
- Of the 89 students who declared themselves to be pursuing a Masters at the time they applied, 13% received a Ph.D., 74% received a terminal Masters, and 13% left without a degree.

(See charts later in this section.)

Appendix E provides information on every Ph.D. and Masters graduate between Summer 1989 and Autumn 1999 inclusive. (Note that this is not precisely the same set of students just characterized.) The first item in the appendix shows Ph.D. students in chronological order, with advisor, thesis title, first position, and current position. The second item is a compact list of Ph.D. students and their advisors. The third item shows terminal Masters recipients in chronological order, with thesis title and advisor.

Summary data is provided on several topics later in this current section: the research area breakdown of the Ph.D. graduates since 1989, the declared research interests of the Autumn 1999 entering class, a tally of each advisor's Ph.D. advisees, and a tally of each advisor's terminal Masters advisees. Following this is a histogram showing the time to Ph.D. The average is 71 months – about 6 years – and has been relatively stable over the decade.

As a faculty, we are generally satisfied with our full-time graduate program. Our Ph.D. program was ranked sixth in the nation for "effectiveness" in the 1993 NRC study. Several times in the past decade we have produced graduates who were among the half dozen most sought after in the nation. (We expect to produce two such graduates this year.) Regularly we produce graduates in the very next echelon. We view our students as a collective responsibility, and we pride ourselves on sending well-educated, well-prepared, already-known graduates onto the interview circuit.

Program design and management

All aspects of the graduate program are oriented towards immersing students in research. It goes without saying, of course, that our view of how best to accomplish this changes from time to time.

In terms of management of the graduate program, we have made changes to the Qualifying Evaluation and to the General Examination this year in order to control what we perceive to be an incipient lengthening of the time to Ph.D., and also in order to reduce the time spent in the

Ph.D. program by students who ultimately leave with a terminal Masters degree – in each case, unintended side-effects of the last round of changes to our exam structure in 1991. (At that time, we changed from a Qualifying Examination consisting of 9 half-hour exams in 4½ hours, to a Qualifying Evaluation consisting of breadth and excellence demonstrated through performance in courses, plus a project/writeup/presentation supervised by two faculty members – with the laudable goals of better allowing students to gain breadth and begin the research experience, and better allowing faculty to assess Ph.D. research potential.)

Careful review of the 150 students admitted since Autumn 1985 who left the department with a Masters degree (see the attached histogram) revealed that while 63% left immediately after receiving their degree, and an additional 11% left within 6 months, 12% remained between 6 and 12 months, 7% remained between 1 and 2 years, and 7% remained more than 2 years. These latter two categories – the students who exited the department a year or more after receiving a Masters degree – were of particular concern to us (even though in terms of raw numbers this group represents fewer than 2 students per year). Further, examination of the 41 students admitted since Autumn 1985 who left the department with no degree at all (see the attached histogram) revealed that these students spent on average a bit more than two years with us before leaving. (A brief note to avoid outright alarm regarding these 41 students: until a change that we made a few years ago, passing the Qualifying Evaluation was not sufficient to earn a Masters degree, so a student could get through the Qualifying Evaluation, subsequently decide that a Ph.D. was not for him/her, and leave with no UW degree. This is no longer the case.)

In response, the Qualifying Evaluation – which involves demonstrating breadth and excellence in coursework and completing and presenting an independent project – must now be completed within 2.25 years of entry to the program unless a petition for extension is granted. The General Examination – which has a variety of formats all centered on integrating the literature in an area – must now be initiated within 3 years of entry to the program or within 1 year of completing the Qualifying Evaluation (whichever is later), and has a duration limited to 2 months. In each case, the goal is to control “scope creep” and move students more rapidly through the “decision points” that mark the path from entry to Ph.D.

These are only the most recent changes in a program that undergoes continuous examination and tuning. Other examples in the past few years include re-organizing the “two from column A, three from column B” structure of the coursework portion of the Qualifying Evaluation to provide greater flexibility for students; requiring students to take two second-tier graduate courses after passing the Qualifying Evaluation; ensuring that students TA for two quarters before receiving a Ph.D.; dramatically increasing and restructuring our mentoring of TAs; and supplementing UW-funded TA stipends using departmental funds so that TAs and RAs are paid equivalently. Our students suggested some of these changes and were extensively consulted on and endorsed all of them.

F. Results of surveys of graduating students

In Appendix M we have included the results of the most recent annual survey of graduating students conducted by the Office of Educational Assessment. Our interpretation of these results:

Relative to other programs at UW, our Bachelors students have a higher involvement in internships and in faculty research (bottom of page 3), and are highly satisfied with the quality of instruction they receive in our department and with the assistance we provide in finding

employment (bottom of page 4). Our students are relatively less satisfied with their preparation in writing, speaking, and critically analyzing information (top of page 4); we have made some changes (e.g., integrating a Technical Writing course with our Capstone Design Courses) to address this. We note that only 41 of 111 Bachelors graduates returned this survey. (In particular, the employment data (page 11) is definitely not representative.)

Relative to other programs at UW, our Masters graduates are tremendously satisfied across-the-board (page 7).

Our Ph.D. graduates also seem relatively highly satisfied (page 10); we find the low results for "working in a group" and "preparing for a career" to be curious and will investigate.

G. Enrollment trends

Enrollment trends for the Department of Computer Science & Engineering are shown in graphical form on an accompanying page:

- In the past nine years, enrollment in our introductory course sequence has grown from 500 students per year to 2500 students per year – a factor of five.
- Our overall count of departmental majors (Bachelors, Masters, and Ph.D.) was 400 in 1995-96; it will be nearly 700 by next fall – a 75% increase in five years..
- In 1990 we did not offer any Extension "Certificate Programs." Last year, these programs enrolled more than 3,500 students and granted more than 600 multi-course certificates.

Additionally, the University of Washington, in many cases with considerable assistance from CSE, is responding to the region's IT workforce needs in other ways: the creation of the Applied and Computational Mathematical Sciences program; the creation of the C&SS undergraduate programs at UW-Bothell and UW-Tacoma; the explicit labeling and subsequent growth of an IS option in the School of Business; the revamping of the Graduate School of Library and Information Science into a modern School of Information which will offer a Bachelors program. A second page of charts illustrates some of these trends.