A New MSE Curriculum

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ABSTRACT

The MSE Department at MIT has developed a new undergraduate curriculum, and has implemented it for Sophomores in the 2003-2004 academic year. The Junior and Senior year curricula will be implemented as the current Sophomores advance. In addition to major core topic additions such as biomaterials and computational modeling, the new curriculum features a novel mixing of laboratory and lecture hours. This permits students to experience hands-on applications of materials in the laboratory immediately after covering the associated theory in lecture. The curriculum was developed in consultation with both students and our external community (Visiting Committee, ABET, alumni), and it required construction of substantial new laboratory facilities. It also required a novel approach to scheduling, in which some loss of flexibility was accepted to gain coherence and relevance of topics.

DRIVING FORCES FOR CURRICULAR CHANGE

The Department of Materials Science and Engineering (DMSE) at MIT began rolling out a totally revised undergraduate curriculum in Fall 2003, with new departmental Sophomores falling under the new system. While the DMSE faculty felt the previous curriculum was performing satisfactorily in introducing the essentials of the field to students, certain strains were becoming increasingly evident. Even though curriculum revision is a difficult and time-consuming task, several unavoidable driving forces for change had appeared:

- The previous curriculum had been in place, changed in detail over the years but basically the same, for almost fifty years [1]. The faculty and student members of the Departmental Undergraduate Committee had a sense of its having become obsolete in many regards, and had already been leaning toward revision.
- Student enrollment in DMSE had been steady or slightly declining for several years, and there had been continuing concern for the reasons for this and how to reverse it. Many factors, such as perception of eventual job opportunities after graduation, certainly influence a student's choice of major. However, the student perception of the curriculum is vital.
- Input from students through their advisors and also from various subject assessments seemed to indicate a growing dissatisfaction with the existing curriculum: it was felt to be much too theoretical, tedious and divorced from practical concerns. Students are generally attracted to MSE by their perception of the many opportunities in the field for exciting research and design innovation, and were displeased by having to work through several years of theory before seeing actual applications.
- The Department underwent its first accreditation review under the new ABET 2000 system in 2001, and even though accreditation was granted the review seemed to highlight the diminishing excitement the staff and students felt for the curriculum. The Department Head, Prof. Subra Suresh, felt strongly that something had to be done, and told the ABET reviewer clearly that a new curriculum would be implemented in the next few years. This push from the Department Head, in concert with the factors already mentioned, was vital in getting this very large task underway. He appointed an *ad hoc* committee chaired

by Prof. Donald Sadoway to put the revision in motion, with a charge to move quickly and innovatively.

THE CURRICULAR REVISION

As is often the case in university curricula, the DMSE undergraduate program is divided into a "lower-tier" core segment of essential topics for sophomores and juniors and consisting of subjects that all students must take. This is followed by an "upper-tier" segment containing a number of restricted electives that build on the core and that allow students an opportunity to specialize as they wish. The curriculum revision has been focused on the core, with upper tier subjects being largely unaffected for now. The core as it existed prior to the revision is outlined in Table 1 below.

Table 1. The previous DMSE core.

	Fall	**Spring**
Sophomore	Thermodynamics	Physical Chemstry
	Structure	Chemical Physics
		Structure Laboratory
Junior	Mechanics of Materials	Transport Phenomena
	Materials Processing Laboratory	

These subjects are very traditional and had been continuously fine-tuned over the years. The instructors, with the Undergraduate Committee providing a loose oversight, had been diligent in keeping the topics up to date and adapting to new technological resources such as web delivery and computational tools. There was nothing wrong with them in terms of their rigor or thoroughness of coverage. However, they were very focused and theoretical. As stated earlier, students often found them tedious and unconnected to the exciting applications that had drawn them to MSE originally. Both students and faculty came to feel that there had to be a better way to present this material, while remaining adamant that the rigor and thoroughness of the teaching must be maintained.

As the revision took shape, the educational objectives of the MSE curriculum remained as they were stated to the ABET reviewers in 2001:

- Provide a solid foundation in the fundamentals of the field of materials science and engineering
- Provide a balance between practical, industrial needs and a solid foundation in fundamentals in addressing engineering problems
- Provide an education that allows students to understand that materials are enabling and integral to the design and fabrication of engineering systems that serve society
- In recognition that contemporary graduates of DMSE often follow diverse career paths, provide education that prepares them to be lifelong learners

- Prepare students for positions of leadership in the field of materials science and engineering
- Provide state-of-the-art equipment and computational facilities in preparation of students for industrial and research careers.

At a Departmental off-campus retreat in 2001, Prof. Sadoway presented his committee's recommendation that not only did the individual core subjects require a top-to-bottom updating, but that they be strongly coordinated and interrelated in a given term to provide a much more unified delivery. This included some pruning and shrinking of older topics, such as certain parts of Gibbsian thermodynamics and quantum mechanics, to make room for newer material, such as biomaterials and lecture-related laboratory exercises.

However, the most far-reaching aspect of his proposal was the strong coordination between the various subjects being taught in a given term, including laboratories and mathematics. He proposed that the Department schedule and interlock almost the entire day during the semesters of the core program, bringing the students into an all-day schedule of lectures and laboratories in which the various instructors worked continuously to interrelate the topics. For instance, the mathematics/computation subject could treat topics in linear algebra and matrix methods just prior to the students covering tensorial treatments of crystallography in the structure subject. This approach sacrifices substantial student flexibility in scheduling, and the faculty was concerned that this would diminish the very student enrollments we were trying to increase. However, Sadoway argued that the pros would outweigh the cons, and with some trepidation the Department voted to move ahead in developing the new program. (As the new curriculum took hold in 2003, even the skeptics came to feel the revision was a very good thing.)

The Sadoway model was debated and modified over a period of some two years, including consultation with student, alumni and industrial friends in addition to departmental faculty. Although the Sadoway proposal was altered somewhat as the program took shape, the new curriculum remained true to his original vision and came to include the subjects listed in Table 2 below:

Table 2. The revised DMSE core.

	Fall	**Spring**
Sophomore	3.012 Fundamentals: Bonding, Energetics, Structure	3.022 Microstructural Evolution
	3.014 Materials Laboratory	3.024 Electronic, Optical and Magnetic Properties
	3.016 Mathematics for Materials	
Junior	3.032 Mechanical Properties	3.044 Materials Processing
	3.034 Organic and Biomaterials Chemistry	3.042 Materials Processing Laboratory

At first glance, this program does not appear dramatically different than what existed before. The coverage of the various subjects, however, was developed using a clean-sheet approach by a

team of faculty with expertise in the subject. This team development required constant negotiation and compromise, since naturally each professor would like to see her own specialty covered in greater detail than would actually be possible, or desirable in an introductory subject. But in time, each subject came to reflect a consensus of experts, and is well matched to the educational objectives given above.

SCHEDULING AND UNIFICATION

As an example of the subject coordination and unification mentioned earlier, a synopsis of the day-by-day scheduling of the Sophomore Fall subjects is given in Table 3 below. It was considered vital that laboratory exercises be offered quickly after matching topics appeared in lecture. This was done by lecturing for two weeks, then moving the entire class into a laboratory mode for a week. Recitation periods were offered every other day in both lecture and laboratory weeks, in which the class was divided into small group sessions for more individual attention. The two-week lecture sequence alternated with the one-week laboratory sequence for the duration of the term. Note that all five days of the week are scheduled, and almost all available hours during the day. This "just-in-time" scheduling is an essential feature of the new curriculum. The instructors of these subjects sit in on each others' classes, and discuss ways to connect the topics on a continuing basis.

Table 3. Daily schedule - lecture weeks

M	T	W	Th	F
10-12 Energetics lecture	1 or 2 Energetics recitation	10-12 Energetics lecture	1 or 2 Energetics recitation	10-12 Energetics lecture
1-2 Math lecture		1-2 Math lecture	12 or 1 Math recitation	1-2 Math lecture

Laboratory weeks

9-1 Laboratory	1 or 2 Laboratory recitation	9-1 Laboratory	1 or 2 Laboratory recitation	9-1 Laboratory

CONCLUSIONS

It is still early in the implementation of the revised curriculum; only the first term Sophomore subjects have been delivered. However, the assessments to date of the new system have been extremely favorable. Instructors have felt pleased by their in-class assessment of student learning, and student-satisfaction evaluations conducted both at mid- and end-term have been glowing as well. Table 4 below shows some of the numerical averages from the student assessments for the three Fall-term subjects.

Table 4. Student Assessment Summaries

	3.012 Energetics	3.014 Laboratory	3.016 Mathematics
Level of interest[1]	5.79	5.75	6.33
Quality of teaching[1]	6.39	6.00	6.58
Use of information technology[1]	6.61	5.67	6.91
Pace[2]	4.78	4.48	4.75
Hours spent per week[3]	12.6	21.1	11.1
Overall rating[1]	4.79	5.06	5.92

1: 1-7 point scale (7=best, 1=worst)
2: 1=too slow; 7=too fast
3: Sum of lecture, laboratory, homework hours per week, averaged over the term

Even before the Fall 2003 subjects were delivered, students had the opportunity to assess the new program all during the previous year, as it was presented to them in web pages, focus groups, open houses, etc. Figure 1 below shows the enrollment history for the Department over the years, and the worrisome trend through the classes of 1999 through 2005 is evident. However, the class of 2006 (Sophomores entering the Department in Fall 2003) represented a strong increase, and in fact that class was the largest in the Department's history. It remains to be seen whether or not this much-welcomed trend will continue, but it appears for now that the new curriculum has lived up to all our hopes.

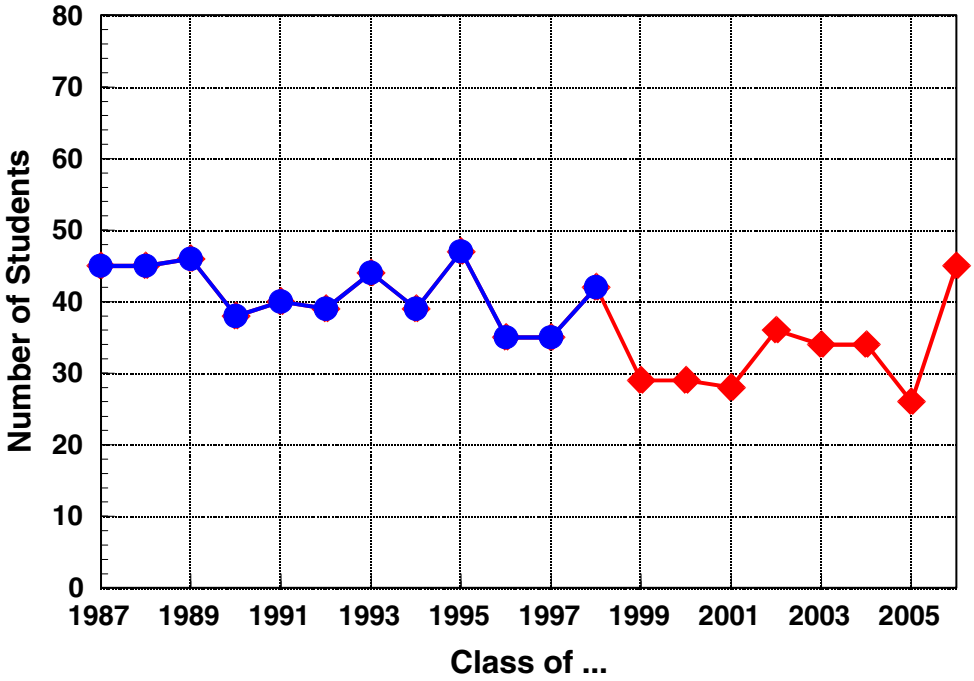

Figure 1. Size of entering DMSE Sophomore classes. (The graduation Class of 2006 are those entering the Department as Sophomores in Fall 2003.)

ACKNOWLEDGMENTS

Obviously, a large number of faculty, students, alumni and friends contributed to the curriculum revision outlined in this paper. However, special note must be made of the vital contributions of the Department Head, Subra Suresh; the Chair of the Curriculum Revision *ad hoc* committee, Donald Sadoway; and the Chair of the Departmental Undergraduate Committee, Caroline Ross.

REFERENCES

1. M.B. Bever, *Metallurgy and Materials Science and Engineering at MIT: 1865-1988,* MIT, Cambridge, MA, 1988.