AC 2003-180: INDUSTRY - EDUCATIONAL PARTNERSHIP FOR MICROELECTRONICS ENGINEERING TECHNOLOGY PROGRAM

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Industry - Educational Partnership for a Microelectronics Technology Program

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Abstract

By responding to the needs of many organizations, a critical mass of faculty and industry expertise has been assembled around the Microelectronics Teaching Factory (MTF) at ASU's East Campus. With students from the University and local Community Colleges, the aggregate number of students provides a large load for the MTF. All students (and faculty) follow the same safety training and industry-standard qualification. The BS classes follow a sequence: web-based preparation; simulation to explore key relationships; MTF lab work appropriate to the degree level; class work to integrate the learning experience and internship or project in one of the participating companies. The goal is to develop an efficient learning environment that meets the needs of all stakeholders – industry, academics and students.

1. The changing educational landscape

A long-standing characteristic of good technology education has been its blend of classroom and laboratory work. High technology subjects such as microelectronics face many new pressures to sustain this goal. The weak business conditions since Fall 2000 have dramatically affected the semiconductor industry and its workforce while the knock-on effects on the State economy have put severe pressure on University budgets.

In spite of weak sales growth, the pace of semiconductor technology development has not slackened. The Technology Roadmap has become more aggressive (1) and global competition has noticeably increased. One of the results of cost pressure has been a substantial reduction in the internal training capacity of most US companies.

Arizona has a large semiconductor industry with Intel, Motorola, STM, Microchip, TI, Medtronic, ON Semiconductor and ASML as the leaders. Total employment exceeds 25,000 and more than half have some level of technical qualification. However, with a new technology generation every 2 years, there is a need for continuous skills upgrading and the majority of students taking technology courses in ASU (or the Community Colleges) are already working in the industry. Students are seeking courses that will prepare them for the technology of the future and the skills to map out the knowledge and credentials their future career plans require.

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Higher education budgets are not exempt from the reductions in State expenditures. This makes it difficult to deliver an experimental program in a subject such as microelectronics where the lifetime cost of ownership of a single process tool (acquisition, installation, services and maintenance) can be many tens of millions ($).

Given these working conditions, an ad hoc partnership has developed around the Microelectronics Teaching Factory at ASU East campus. The goal is to create the technology analog of a teaching hospital where practitioners, faculty and students work together on realistic problems. Industry sees advantage in having access to a sound educational base that can address the needs of the entire workforce. Companies provide resources through a high-level Advisory Board (monthly meetings), equipment donations and support for preparation and delivery of classes and lab activities. The Community Colleges, gain access to a first class facility as well as ASU courseware that can be adapted for faculty development or AAS courses. ASU gets more customers to load its facility and access to a wide range of expertise to complement the faculty. The arrangement is shown schematically in figure 1.

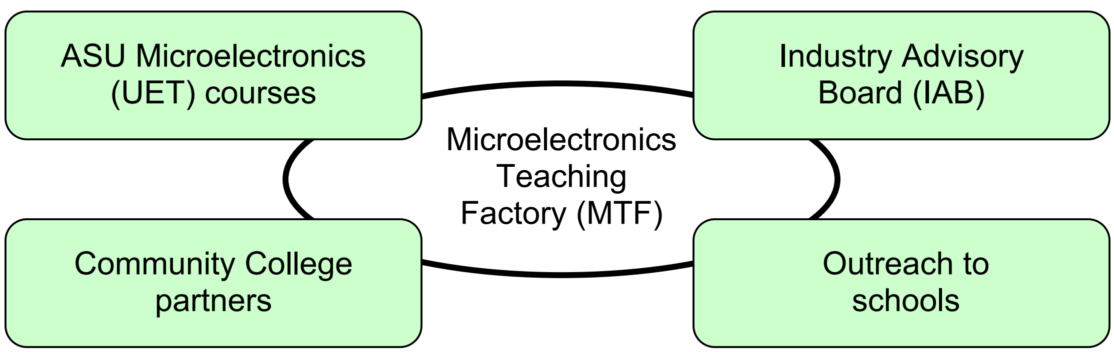

Figure 1. Principal MTF relationships

2. Microelectronics curriculum

The most significant outcome from the broad curriculum discussion with the IAB has been to spell out the skills and competencies expected in a graduate. Fortunately, this also aligns well with the ABET process. In our case, the analysis gave a list of skills that are invariant (or at least change slowly) plus a second list that reflects current practice and finally, identification of missing topics. The next section of this paper describes how the curriculum has been developed to deliver these skills.

Slowly changing knowledge and skills	Skills that reflect current practice
Basic science, materials and devices	Process, tool and product design
High level of numeracy (NOT same as conventional math skills)	System partitioning – especially between hardware and software
Reduce a problem to a workplan (think!)	How to interpret the Technology Roadmap
How to execute an efficient workplan	Operational efficiency and cycle time
Structured information collection	Assess non-refereed information
Sources and management of variation	Manage an excess of data
Maintain a high safety culture	
Appreciate cost, customers and time	
Presentation skills (all forms)	

The gap analysis quickly showed that most of these topics were (at best) only covered implicitly in conventional courses. We also developed a much clearer specification of the expected outcomes from basic science and math courses – although realizing them with service departments is no easier at ASU than elsewhere. Design issues and the International Technology Roadmap for Semiconductors (ITRS) (1) fit neatly into dedicated courses. We also provided a new introductory course at 300-level to cover business (economics, global scope and skills), product design (system decomposition, voice of customer and FMEA) and process design (drivers, state-of-the-art and cost models).

Most topics in the above table, however, do not fit neatly into any single course or category. They have to be spread across the whole curriculum as a working style that is consistent, visible and where the desired outcomes are clearly rewarded. This in turn requires new course structures that allow the students to practice these skills individually, in groups, at work, in the lab as well as in the traditional classroom setting. There has been no problem with student acceptance of the principles. "Just like work" is the usual response.

3. Delivery

A number of delivery options have been assessed (2, 3). We have tried many combinations of web, class and lab activities. The conclusions are very much based on the particular requirements of our student community and the constraints imposed by the slim resources available for any innovation. The major operational factors are:

- Manage courses as combinations of 1-credit modules.
- Do as much background preparation as possible on the web. ASU has a portal that is based on Blackboard software and it works well for this purpose.
- Concentrate class work for each module into 1 or 2 whole days. This is possible because the College does not schedule conventional classes on Fridays.
- Integrate simulation and lab work with each module.
- Allow follow-up projects or internships in industry (for additional credit).

The primary goal is to create a strong learner-centered environment and these innovations certainly move us in that direction. The generalized structure of a single course is shown schematically in figure 2. Since our students usually do not progress through their course as a lock-step cohort, the preparative section takes on greater importance. It looks back to specific parts of lower division courses that may have been taken several years earlier. It also puts the course into the perspective of the whole curriculum. Self-paced web delivery works well for this type of learning where the outcomes can be easily verified. The student has to match his own capabilities to the required capabilities and fill in the gaps using a range of support tools. This provides training in generating a realistic personal learning work-plan and coping with a wide range of information sources. There is no single textbook or straightforward authoritative source. As an example, in the module that deals with thermal oxidation of silicon, the basic description can be found in any semiconductor book. In addition, however, there are web papers by vendors and research publications from all the major semiconductor companies. We seek to develop awareness of the utility – and risks – associated with each of these sources. Perhaps the most important learning outcome from this activity is that it provides students with practice in how to schedule their time with fuzzy constraints but still take personal responsibility to deliver on time – "just like work".

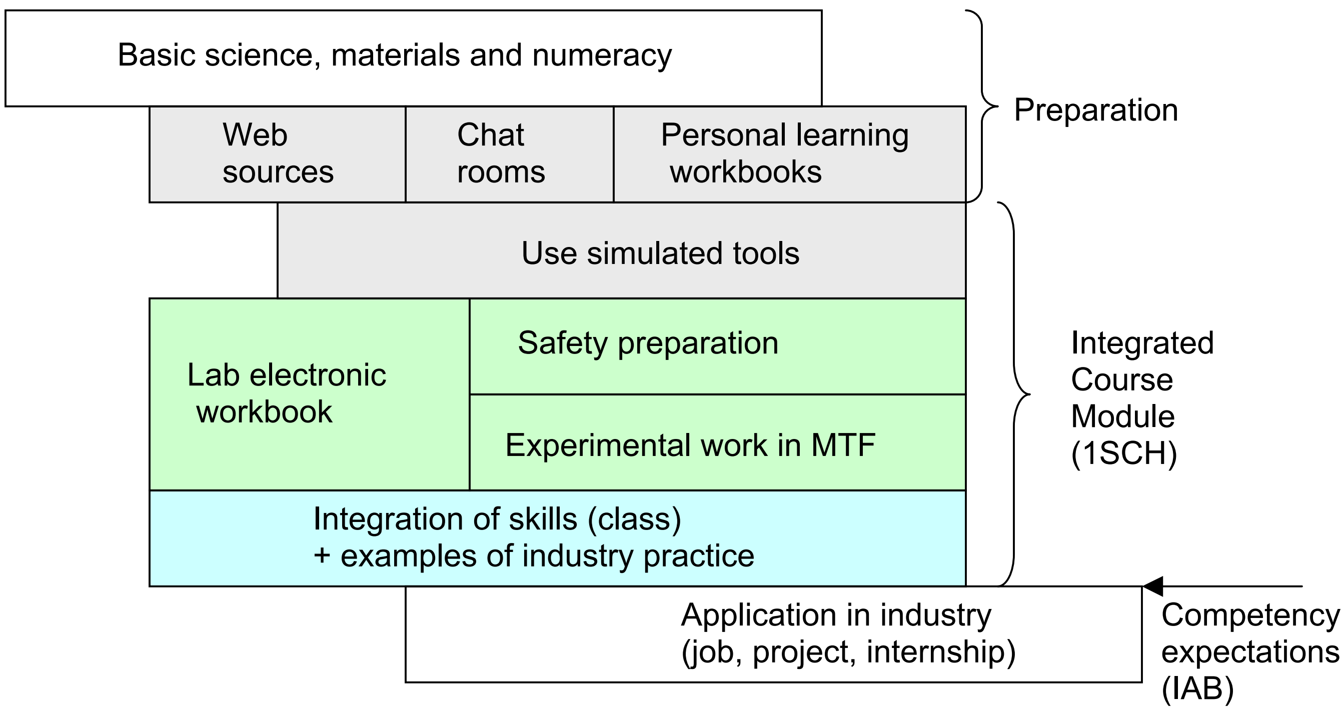

Figure 2 Framework for single course module

Tool simulators are used to give students some insight into the operation of typical process tools before they go into the lab. The operator interface to a tool is invariably via a computer screen. By using a virtual machine on a PC, the student can learn to navigate the screens accurately and safely before seeing the real tool. It makes "clean room time" much more productive. We also use higher-level simulators for "what if" analysis. They are usually Excel-based and allow the sensitivity and interactions of the major parameters to be explored.

A whole-day class provides a lot of flexibility. We typically cover 4 types of activity:

1. Students give individual or group presentations on their preparative work
2. New or more complex topics are treated using conventional lecture format.
3. Lab demonstrations can be arranged. They concentrate on process outcomes - especially the scale, classification and control of variation.
4. Examples of industry practice. Concentration on a single topic allows a specialist from one of our partner companies to give illustrations of current operations.

The concept works well for microelectronics and to date, we have 14 course modules at 400/500 levels (1 SCH each). Grading is very conventional but with significant weight given to critical thinking to find balanced technology solutions. As a result, the grade reflects the student's combination of competency and contextual understanding. One practical issue is that there is a wide spread in preparation time within the class.

4. Benefits of scale

BS classes are the core for microelectronic development in the MTF. However, the structure described in Figure 2 is built on a large database – lecture slides, simulations, student activities, process and tool operations, services, etc. It takes a lot of work to create that base, but it can be exploited in many ways. One of the most important functions is to support community college faculty development and assist their students to use the lab facilities (4). The microelectronics program currently has 25 students and it is planned to grow by 20% per semester to a ceiling around 100 students. There are 10 participating community college faculty and together, they have about 100 students who will eventually carry out some component of their practical course work in the MTF.

We seek to emulate industrial practice where many people with widely varying skills and qualification all work together in a single plant. The starting point is safety. As in a company, everyone operates at the same level, regardless of qualification. For experimental work, the activities can be directed to the appropriate outcomes for the class involved. AAS students concentrate more on tool operation, services and maintenance. BS students see more emphasis on measurement and management of variation. The work of each group benefits the other and over time, a wide range of process features can be covered.

5. Conclusions

A strong education-industry partnership has been developed around ASU East's Microelectronics Teaching Factory. To meet the new specifications that have been developed by the major stakeholders, a new BS-level curriculum has been developed with many novel delivery features. The facility and its resources are also being used by the local Community Colleges. Together, the partners seek to build an educational infrastructure that will meet the workforce needs of a global-scale competitive industry.

Bibliography

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Biographical information

John Robertson is a professor in the Department of Electronic and Computer Technology at ASU's East campus in Mesa, Arizona. From 1993 to 2001, he held a number of senior R & D positions in Motorola's Semiconductor Products Sector. His earlier academic experience was as Lothian Professor of Microelectronics in Edinburgh University, UK where he managed a national research center and developed continuing interests in process control and the global economics of semiconductor technology.

Jon Weihmeir is currently a visiting professor at ASU's east campus from Motorola's Semiconductor Products Sector. He joined Motorola in 1984 as a wafer fabrication engineer and worked in R & D as well as production facilities, focusing on diffusion, wafer cleaning, and gate oxide integrity. From 1996 through 2002, he held management positions in process engineering, device engineering, and manufacturing at Motorola in Mesa, Arizona. Jon received the B.S. and M.S. degrees in Electrical Engineering from the University of Illinois and National Technological University respectively.

Lakshmi Munukutla received her Ph.D. degree in Solid State Physics from Ohio University, Athens, Ohio and M.Sc and B.Sc degrees from Andhra University, India. L.V. Munukutla developed an interest in semiconductor device processing technology and characterization while she was working at Motorola Inc. She has been active in research and published several journal articles. She holds an Associate Dean position in the College of Technology and Applied Sciences at Arizona State University East.

Richard L. Newman joined Arizona State University East (ASUE) in August of 2001 and currently serves as Director of Training Operations for the Microelectronics Teaching Factory. In this position Mr. Newman is responsible for the identification, development and delivery of education and training for the semiconductor manufacturing industry. Prior to joining Arizona State University, Richard served twenty years as a faculty member and administrator within the Division of Technology and Applied Sciences at Arizona Western College and the University of Arizona. He most recently held the position of Associate Director at the Maricopa Advanced Technology Education Center (MATEC).