# Microelectronics Teaching Factory, a Venue for Learning and Building Real World Products By Engineering Technology Students

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Abstract

Arizona State University East (ASUE) is leading a project in preparing Engineering Technology students majoring in Microelectronics with real world experiences via integrated learning in the Microelectronics Teaching Factory. The objective is to have better-educated and better-prepared technologists to meet the workforce needs of the region's semiconductor industry. The strategy is to consolidate major integrated learning activities into a single world-class facility known as the ***Teaching Factory***. The Microelectronics Teaching Factory (MTF) at ASUE is capable of producing fully functioning integrated microchips, and has established a partnership with a number of major semiconductor manufactures and regional Community Colleges.

## Introduction

The state of Arizona, primarily Maricopa County, is a nationally recognized hub of semiconductor fabrication. Where the national average of employment concentration in the semiconductor industry is benchmarked at 1.0, in Arizona that concentration is 6.8. The jobs are here via industry leaders such as Intel Corporation, Motorola, Inc., Microchip Technologies, ST Microelectronics, Amkor Technology, Inc., ASML, and Medtronics, Inc., as well as many smaller manufacturers and suppliers. In 1999 jobs in Arizona's semiconductor and related electronics and computer industries numbered nearly 55,000. Wages paid for these jobs by the region's semiconductor and related companies were 92 percent higher than the state's average wage (1,2). As of 2000, semiconductor fabrication is the nation's largest manufacturing activity, and the State of Arizona ranks 3rd in the nation in semiconductor employment with 33,500 jobs (3).

Yet a survey of Arizona's high-technology firms recently completed for the state's Department of Commerce revealed that 73 percent of the region's high-tech job openings either went unfilled or were filled by people relocating to Arizona. In responding to the survey, 60 percent of the company executives stated that a shortage of skilled workers was the most or one of the most significant problems facing their business. ASUE is positioned well to meet the workforce

demand of these companies, and with the help of these industry partners and the Arizona State Legislators the MTF became a reality.

Semiconductor manufacturing survives by rapid change to develop, produce and market new products better, faster and cheaper than the competition. The most flexible fab employees run production, make process-engineering decisions, manage workflow, maintain the equipment, and train as a team. These flexible skill requirements presuppose a broad knowledge in science, math and communications. However, few employees are that versatile. This paper describes implementing an integrated learning model at all degree levels in MTF at ASUE to bridge this gap.

Integrated Learning Model

The pedagogical model of the MTF is integrated learning—learning in which students prepare by learning and practicing principles of semiconductor processing and then practicing those processes on actual tools. The aim of all courses is to allow students to develop their individual competencies in a way that satisfies the context in which they are applied. In contrast, the classical academic model starts with basic science and may (if there is time) briefly cover a few practical applications. In the Teaching Factory, practical applications are not optional. We have adopted many of the features of a ***just in time*** process in developing our curriculum modules to prepare students for employment.

One dilemma facing programs in semiconductor manufacturing technology (SMT) is the expense of realistic lab facilities. If a semiconductor fab costs $1.5B, it stands to reason that no realistic demonstration lab will be inexpensive to build and operate. Even in states with generous education resources, costs are making it ever harder to maintain SMT lab capability on multiple campuses. Arizona is typical in this regard. Three of the state's community colleges have well regarded SMT programs, but full-scale demonstration labs have not been affordable. The absence of realistic lab training opens a steadily widening gap between the basic science and engineering taught in the academic world and the complex, expensive, and interactive technology used in the industry. Company managers report that most new graduates need stronger skills in 1) operating and troubleshooting semiconductor tools and processes; 2) understanding the technology's operations and limits; and 3) interacting with colleagues, suppliers, and customers.

The Microelectronics Teaching Factory is designed to fill this need. Industry clearly believes the integrated regional solution to expensive laboratory instruction can ease workforce shortages. Intel already collaborates in a regional lab serving multiple campuses in New Mexico, and Texas Instruments supports a regional lab model in Texas. Regional companies have already given the Teaching Factory their vote of confidence through major donations of equipment and pledges of continuing support. Our partnership aims to prepare technicians and engineering technologists with BS and MS degrees so soundly prepared in technological principles, processes, tools, skills and work habits, that they can contribute to a company's bottom line on the day they are hired.

Industry has limited opportunities to influence the education of its prospective employees, and the first feedback educators often receive is when graduates fail to meet performance standards in the workplace. The Teaching Factory aims to create satisfied customers among the region's semiconductor companies by heavily involving industry in curriculum design, program implementation and formative evaluation. Then, through assessments of all sources, including

feedback on students' workplace performance, adjust curriculum and program goals to continuously improve.

Figure 1 shows how the MTF is part of an Integrated Learning Model adopted for curriculum development, and delivered to the students through learner-centered activities.

*Integrated Learning Model*

| Who \ Where | Class | Teaching Factory | Company |
|---|---|---|---|
| **Students** | Learn Principles | Hands-on learning, Practice | Contribute, Build career |
| **Faculty** | Teach Principles | Supervise, Assess | Observe skills, See new technology |
| **Industry** | Mentor, Advise on content | Mentor, Set priorities | Assess graduates, Spec future needs |

**Figure 1**

**MTF FACILITY**

The Microelectronics Teaching Factory exemplifies the best in public/private partnerships. It is housed in a building that was constructed using $6M of State of Arizona appropriated funds at ASU East campus. Intel, Motorola, Microchip, Amkor Technology and others donated the late generation 150-mm tools that had an estimated new value of $7M. The MTF is a 15,000 square-foot, full-process teaching model of a semiconductor manufacturing cleanroom at ASU East that contains the major process tools required to manufacture functioning integrated circuit microchips. However, at this time the project is still in its infancy to make a realistic projection of operating expenses and more definitive assessment will be feasible within a year. It is as close as a student can get to the semiconductor work experience without stepping foot on a commercial factory floor.

The MTF is housed in the College of Technology and Applied Sciences (CTAS) at ASU East, the university's lead campus for engineering technology degree programs. The Teaching Factory is the first laboratory learning venue in the region equipped to provide full-scale, industry-guided, factory-based education for community college and university students preparing for careers in semiconductor manufacturing. The goal is to attract freshman and also community college transfer students into our four-year BS Engineering Technology program. The Teaching Factory gives Arizona's community college students access to a regional Semiconductor Manufacturing Technology (SMT) facility that is prohibitively costly to provide on individual

campuses. Also, it provides a venue and the infrastructure to coordinate an intensive campaign of student preparation for an industry that is indispensable to Arizona's economic future.

## Benefits

The Teaching Factory produces targeted benefits for:

### Students

- Opportunity to practice on the manufacturing processes, tool, and build work skills in a world-class facility
- Learn to accommodate factory conditions contextual environment that models the work
- Opportunities for interacting with industry mentors
- Develop industry contacts that are helpful for career guidance and job placement

### Faculty

- Ability to offer students instruction in a superior regional facility that individual campuses could not afford to build, equip, and operate
- Faculty interaction with industry trainers, technicians, engineers, and managers
- Faculty development of deepened content knowledge and technical skills
- Collaboration between institutions yielding improved learning for students
- Opportunity to build superior lab curriculum

### Industry

- Opportunity to influence the content, quality, and evolution of the education of the emerging workforce
- Identification of outstanding graduates for workforce recruitment
- Reduced learning curve and training costs for new employees
- Improved recruitment of students into technology education

## Conclusions

Arizona is home to a significant cluster of semiconductor manufacturers and related companies that causes it to be known as the Silicon Desert. Nonetheless, like high-technology firms nationwide, Arizona's semiconductor industry suffers a persistent shortage of "job ready" engineering technology graduates. Part of the deficit stems from a problem that negatively impacts on workforce education across the country. With few exceptions, community college SMT (Semiconductor Manufacturing Technology) programs cannot afford the equipment required to field strong factory-based education programs. In response, ASU East has developed and made available to the state's two-year colleges the Teaching Factory, the region's only full-scale, industry-guided, factory-based laboratory knowledge venue for community college and university students preparing for careers in semiconductor manufacturing. The MTF provides better-educated and fully competent semiconductor technologists to meet the needs of the region's semiconductor industry.

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Biographical Information

LAKSHMI V. MUNUKUTLA

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.

ALBERT L. MCHENRY

Dr. Albert L. McHenry is Professor and Dean of the College of Technology and Applied Sciences at Arizona State University East, Mesa, Arizona. He holds a BS Industrial Technology form Southern University of Baton Rouge, Louisiana, a MS Technology and a Ph.D. Technical Education from Arizona State University. His area of technical specialization is digital electronics. His current research interests include noise in digital systems design methodology and effective paradigms in engineering technology education. He is Co-director of The Western Alliance to Expand Student Opportunity, a National Science Foundation Alliance for Minority Participation project. Dr. McHenry has been actively involved in four-year technology programs for over 35 years. He was the recipient of the 1996 ASEE, Fredrick J. Berger Award and is presently the Chair of the Engineering technology Council and a member of the ASEE Board of Directors.

JOHN ROBERTSON

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.

RICHARD L. NEWMAN

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). MATEC is a national center of excellence funded by the National Science Foundation (NSF) that focuses on workforce development for the semiconductor manufacturing industry.