

CONTEXTUAL EXPERIENCE MODEL TO PREPARE HIGH TECHNOLOGY WORKFORCE

Lakshmi V Munukutla¹, John M Robertson² and Albert L McHenry³

Abstract *Arizona State University East has established a partnership with a number of major semiconductor manufacturers and the local Community Colleges to deliver an integrated educational program for workforce development. It is built around a multi-use Teaching Factory where many essential features of technology education can be delivered concurrently at several degree levels. The program uses a common framework for course design combined with a number of delivery modes to suit the topic and the competency requirements of the students. It is a cost-effective and continuously adaptable solution to create an educational environment where the skills for a capital-intensive industry can be realistically developed.*

Index Terms *Semiconductor workforce development, Curriculum design, Multi-mode delivery, Educational partnerships.*

1. INTRODUCTION

The impact of the new economy is very visible in technology education in Arizona. There is a strong concentration of high-tech companies in aerospace (Boeing, Honeywell, Raytheon) and semiconductor manufacturing (Intel, Motorola, On Semiconductor, Microchip, STM, Texas Instruments, and Amkor). All recognize that market and technology changes are endemic and that they must have a solution to two pressing workforce issues. The first is a continuous supply of well-prepared recruits and the second is a process to continuously update and upgrade the intellectual capital of the entire workforce.

The higher education curriculum in Arizona conforms to the traditional pattern of segmentation both by discipline and by qualification level and delivered by Community Colleges and Universities. However, practice-related topics such as quality and process technology require an intimate knowledge of company operations and the capability of the academic sector to address these market requirements has been limited. As a result, starting in the 80s, there was a proliferation of company universities to meet the needs. Now we are entering a new phase which is driven by two complementary pressures:

- The success of company universities in defining a service requirement means that – like most non-product services – the activity can be outsourced with lower costs and improved responsiveness.
- Web-based delivery of courses allows education providers to break out of the ‘classroom straightjacket’ and provide a demand-driven service ‘any time, any place’.

This paper describes how these challenges are being addressed at Arizona State University’s East campus through a ‘Teaching for Innovation’ partnership with industry and the Community Colleges. The initial focus is on the semiconductor industry requirements but many of the concepts have been adapted from aerospace experience and the symbiosis and interplay between the two interest groups are a powerful attribute of the whole approach.

2. SCENARIO

Semiconductor technology evolution has been remarkably consistent for 30 years. Steady reductions in device features have resulted in lower cost and improved performance as shown in Figure 1.

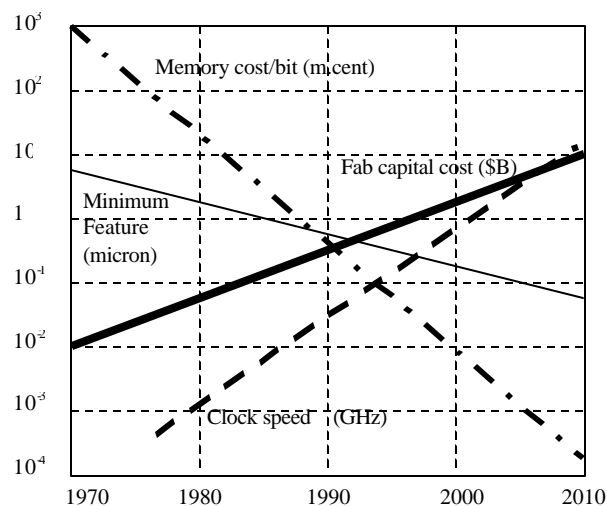


FIGURE 1
SEMICONDUCTOR EVOLUTION SUMMARY

¹ Lakshmi V Munukutla, Arizona State University, 7001 E Williams Field Rd., Mesa, AZ 85212. lakshmi.munukutla@asu.edu

² John M Robertson, jrobertson@asu.edu

³ Albert L McHenry, albert.mchenry@asu.edu

The industry roadmap is updated regularly and the trends look as if they can be reliably extrapolated for the next decade [1]. A less familiar feature of the evolutionary process (which is also shown in Figure 1) is the steady increase in capital cost of the manufacturing plant. Today's \$2B investment every year or two can only be contemplated by very prosperous organizations.

One side-effect of such capital-intensive operations is that the massively increased output from each new plant also means that the world's chip capacity can be met by fewer wafer fabrication plants. There is therefore increasing competition to attract new investment and regions which are already well-established – such as Arizona – cannot assume that success is assured. To add to the challenge, it is becoming increasingly difficult for an educational establishment to keep up with the technology know-how embedded in multi-billion dollar facilities to even begin to meet the anticipated workforce development needs. The challenge is summarized in the scenario shown in Figure 2.

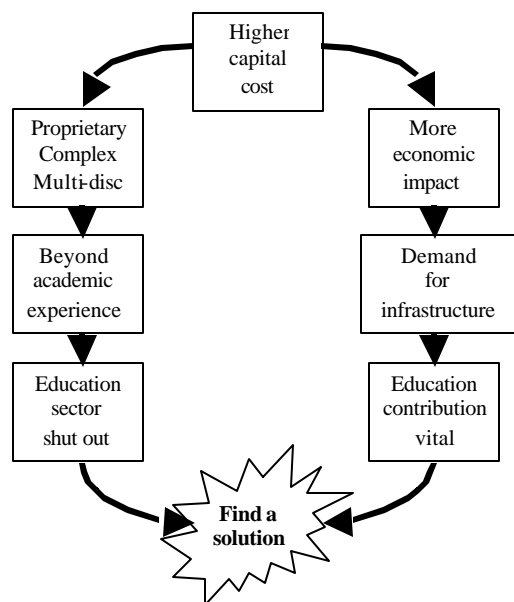


FIGURE 2

THE ACADEMIC CHALLENGE TO PARTICIPATE

Recently, the need for an educationally-based workforce has grown significantly, to support the knowledge economy. The impasse depicted in Figure 2, reflects the inability of traditional higher education organizations to address the new market requirements. There are clear indicators that we must start to develop alternative approaches. The core of the concept of our innovation is to simulate the key features of the industry environment within an academic setting. We call it a 'Teaching Factory'. The physical entity is a large

clean-room lab built to H6 industry standards. It therefore allows us to by-pass the 'shut out' scenario shown in Figure 2 and drives our course planning strategy to focus on outcomes that are directly linked to the technology applications in our partner companies.

This means that we have:

- A curriculum that delivers the competency needs of students in the workforce
- Multi-disciplinary and multi-level classes
- An educational framework that complements experience in industry
- Enough hardware to provide the 'look and feel' of an industry setting
- Outcomes that are skills-based and validated by industry.

Economy of effort is the major criterion since courses dealing with expensive technology have to be delivered within a university funding framework that reflects traditional costs and priorities. The high-technology world may be capital intensive, but there is no indication that academic budgets will follow suit.

3. CONTEXTUAL MODEL

The objective of all courses is to allow students to develop their individual competencies in a way that will satisfy the context in which they will be applied. This marks a radical departure from the classical academic format that starts with basic science and may (if there is time) briefly cover a range of generic applications. We have adopted many of the features of a 'Just in time' process:

- Start with the outcomes to define content
- Subdivide all courses into modules
- Provide a roadmap to show how modules interlink
- Allow students to plan their own learning path

One feature that makes this approach feasible is that many of the students are already employed – usually in a semiconductor company or one of its suppliers. It also implies that we can operate comfortably in the role of educational services provider with the students and their employers as customers. The added value brought by the academic community is not detailed knowledge but a capability to integrate the many facets of understanding and skill to meet the standards for effective application.

Modularity allows many delivery options to be used in each course. To offer a consistent package to the students, we have concentrated on 5 components:

1. Conventional class sessions. They provide a vital introductory meeting ground that acts as a platform for the team-working activities that follow. By concentrating class work into half- or one-day sessions, we can more readily fit the work schedules of our students.
2. Distance delivery via ASU's TV network and web-based tools (Blackboard) is already well established for the Phoenix area. However, we see this delivery option best suited to provision of guided reading assignments and to supplement any background deficiencies so students can pace their own work according to their experience.
3. Simulation is a powerful tool to explore the application of basic concepts. As well as reinforcing numerical fluency, the tools can also be used to demonstrate parametric sensitivities and many unusual operational modes can be considered safely. Here there is a lot to be learned from the experience of colleagues teaching pilots. Semiconductor simulation tools have been largely developed as design adjuncts and their use for contextual education is still in its infancy.
4. Lab experience in the Teaching Factory. The TF is a central resource for the whole College and many disciplines are represented as shown in Figure 3. Significantly, the clean room, its services and many facilities can be used in many courses and to teach students at many academic levels. The total area is 15000 sq ft (~1400 m²) and it is populated with late generation 150mm tools donated by Intel, Motorola and Microchip.
5. Project experience either in a company or in the teaching factory. In either case, there are industry and academic mentors. Projects provide the final integration of all the earlier learning experiences in a contextual setting where the emphasis is on competency and effective application.

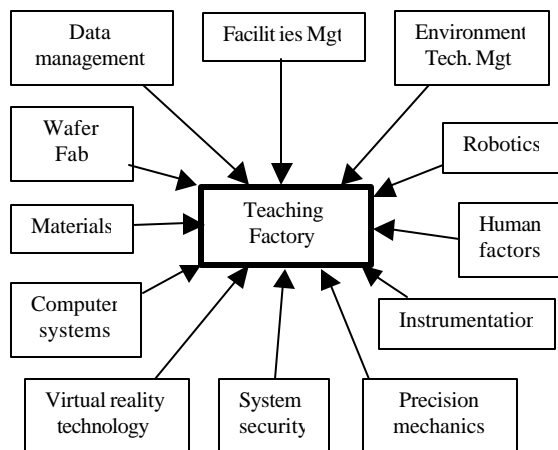


FIGURE 3

Final performance assessments are based on a portfolio to showcase competencies and achievements.

4. Curriculum framework

The higher education structure in Arizona has two distinctive features – the number of students who attend Community College is about twice the national average and in metropolitan Phoenix with a population of over 3 million, there is only one public university, ASU. This means that a partnership between the University and the Community Colleges can cover all the regional higher education needs.

The markets addressed by the education providers have the typical compartmentalized features shown in Figure 4. Within the engineering and technician ranks, there are also many disciplinary subdivisions which become more strongly defined in the later stages of all degree courses.

	Community College AAS	University UG BS	PG MS
Manager			
Engineer			
Technician			

FIGURE 4

The industrial reality, however, is that all categories work together and in all high-tech industries, disciplines must be coupled closely to deliver an optimized product. This is an important cultural effect that can be very readily captured in the Teaching Factory. As a result, our partnership with the Community Colleges allows us to collaborate on curriculum development and its delivery to our respective student groups in the Teaching Factory.

In semiconductor technology, we are fortunate in having a clear and well-tested development roadmap [1]. The dominant parameter is the minimum device critical dimension (CD) and most process evolution follows from the CD requirements. Thus, the 9 basic process steps: diffusion, oxidation, vapor deposition, ion implantation, maskmaking, printing, etching, metallization and wafer finishing all have strong generic features which can be

clearly seen over many generations of equipment, processes and products. We can exploit this feature by using it to establish a common educational framework for courses dealing with each of the above 9 process categories.

The main framework headings are:

- Basic physics and chemistry. They provide the ground-rules which do NOT change with technology development. They also underpin all set-up and troubleshooting procedures so we can establish a very direct link from the science base to economic impact.
- Wafer processing specifications provide the translation from standard concepts to unique and competitive products. In a company, the emphasis tends to be on minimizing variation; in the Teaching Factory, we can explore sensitivities and response surfaces to complement the industry focus.
- Process equipment design is complex and multi-disciplinary and often at the limits of the performance we can expect from the basic science. The tools in the Teaching Factory are used to demonstrate design, operation and process limitations. Reverse engineering is a powerful teaching technique, especially when it is applied to a major item of hardware.
- Measurement and control rely on many physical processes and statistical data management. The results have to be understood in the context of the measurement technique so this category provides a strong link between the basic science and the product. The volume of data collected can be overwhelming and its management is critical for effective process control.
- Every process step had some impact on all the others and on the final product. Simulation can play a powerful role in demonstrating the interactions. The relationships have to be understood and exploited if a truly competitive product is to be generated.

In addition, the same analysis headings can be applied to features that cover the whole process such as: safety, metrology, facilities, packaging, testing, process architecture and even the economics of semiconductor manufacturing. We have therefore created a form of taxonomy to describe a whole industry. It confers a number of very useful advantages:

1. It is the basis of a systematic plan to add new courses and update those we already offer.
2. Students have a common learning framework.

3. We can change the emphasis to suit different degree levels and thus avoid the compartmentalization of Figure 4.
4. Companies can easily add their own proprietary material.
5. There is a common but simple instructional design methodology that can be readily used by the wide range of participants in the program.

At present, our focus is entirely on demonstrating the viability of the Teaching Factory concept with our local community. However, there are many interesting long term development options. Since semiconductor technology is the engine room for improved computing and communications, the number of people who have to understand its principles is very much greater than the number who are directly involved in making chips. Our framework can be easily extended to meet the needs of that international community through partnerships and enhanced distance learning tools.

5. Quality and risk

Any change in academic organization inevitably raises nervous questions about quality. Fortunately, there are good procedures to ensure high quality even in very dynamic environments. We have therefore adopted the ISO 9000 approach to institutionalize a quality process based on visible processes with continuous scrutiny and improvement.

No major change can be implemented without considerable risk. For us, the internal challenge is to balance all the components of the program both against each other relatively and against the available resources to implement the new curriculum. Our development strategy allows for considerable concurrent work on focused projects. The external challenge is to demonstrate how an integrated academic program can give the economic returns that our sponsoring companies need for international competitiveness..

6. Conclusions

We have outlined a strategy built around a Teaching Factory concept. We believe it has the breadth and flexibility to meet the needs of workforce development as well as providing an exciting academic initiative.

[1] International Technology Roadmap for Semiconductors (1999), http://public.itrs.net/files/1999_SIARoadmap/home.htm