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THE GROWING NECESSITY FOR CONTINUING EDUCATION: THE SHORT COURSE OPTION*

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ABSTRACT

Continuing education is a critical issue in the workplace. Rapid change, the emergence of new technology, and the lack of trained individuals make continuing education an imperative for employers. The desire for individual growth and marketability make it an imperative for the employee also. While there are many options for continuing education, an increasingly popular vehicle is the short course. Time, cost efficiency and instruction by those experienced in real industrial practice are key factors in the success of this educational format.

Over the past couple of decades, short course offerings and the number and type of sponsoring organizations have grown significantly. Within the scientific community, courses in basic disciplines (e.g., materials characterization), emergent technologies (e.g., Micro-Electro-Mechanical Systems), equipment operation (e.g., electron microscopes) and even business practices (e.g., ES&H, proposal writing) have emerged and are taught by universities, technical societies and equipment manufacturers.

Short course offerings and formats are evolving. Presently, it is possible to find series of courses which define specific curricula. These curricula set the stage for new developments in the future, including increased certification and licensing (e.g., technologists). Along with such certifications will come the need for accreditation. Who will offer such programs, and especially, who will accredit them are significant questions. Perhaps the most dramatic changes will occur with the integration of advanced information technology. While satellite-based remote offerings are available, the use of the web for educating a dispersed group is just beginning to emerge. In its simplest forms, this offers little advantage over a video or a real-time satellite course, but the eventual emergence of tele-operation of experimental equipment will revolutionize remote teaching.

Keywords: *Continuing education; short course; remote learning; emergent technologies; professional societies*

THE NEED FOR CONTINUING EDUCATION

There are many factors that drive the need for continuing education. Perhaps the most important are: (1) the ever increasing pace of technological innovation and (2) the introduction of new "disruptive technology."[1] We consider each of these in more detail.

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Technology advances at an ever-increasing pace. Perhaps it is never more obvious than in the microelectronics industry, where the complexity of integrated circuits, or chips, doubles every 18 months. As shown in Figure 1 and popularly described as Moore's law, the number of transistors in modern microprocessors has increased by almost four orders of magnitude over the past 25 years.

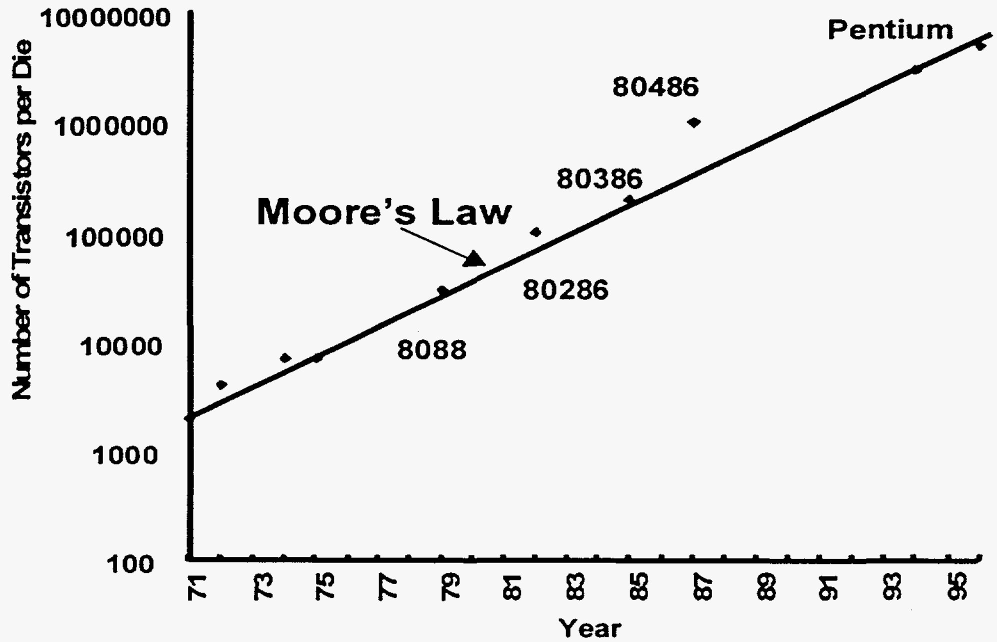

Figure 1. Graphical representation of Moore's Law, first described by Dr. Gordon Moore, co-founder of Intel, showing the doubling of chip complexity, as measured by transistor count, every 18 months.

The impact on the engineer is obvious. A 30-year-old engineer, 8 years post BS, will have seen the complexity of the chips increased by almost a factor of 100 since graduation. Such advances often entail substantial changes in design, materials and fabrication processes. The education the engineer received only a few years back may now be woefully inadequate.

"Disruptive technology" is defined as a new technology so different from that which it replaces that the entire business landscape has changed. For example, the entire watch industry was turned upside down in the 1970's when low cost quartz watches were introduced, virtually completely displacing traditional mechanical watches. The quartz-based watches were significantly cheaper, and extremely accurate. Traditional watch manufacturers who had perfected techniques for building the intricate "Swiss" watches were slow to respond, and were quickly left behind. While some disruptive technologies may be obvious, others are embedded in such a way that they may not be at all obvious. While we are all familiar with automotive airbags, the devices, which sense deceleration and trigger the airbag, have undergone a disruptive transformation. As shown in Figure 2, less than ten years ago all airbags were deployed by a spring and roller mechanism called a rolomite. A mere seven years later, rolomites were totally gone from the marketplace, having been replaced by Si-surface micromachined Micro-Electro-Mechanical Systems (MEMS). While the function of the two devices is identical, the technology used in each could not be more different.

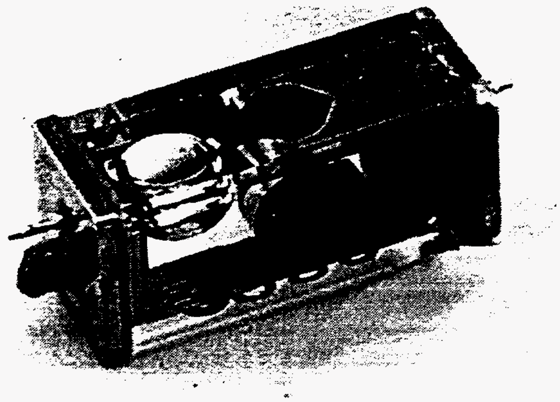

Figure 2. In 1990, all automotive airbags were deployed by rolomites, left, at a per unit cost of $1200.00. By 1997, rolomites had been completely replaced in the marketplace by MEMS – based devices, right. The MEMS-based devices cost less than $5.00 each. This technology although not evident to the consumer, is a radical change and considered a disruptive technology. The engineering skills, including materials engineering skills, required to design and fabricate a rolomite-based and a MEMS-based airbag accelerometer are totally different.

The discussion above clearly describes how technology changes, either evolutionary or revolutionary, can drive the need for new engineering skills in the workplace. Yet, the problem is more complex because the very nature of the workforce itself is changing. Today's young engineering graduates, so-called Gen-Xers and Gen-Yers, enter the workforce with far different expectations than their predecessors. Job mobility is much increased as job security is much decreased. As a consequence, young engineers are often less "loyal" to their employer than in the past. Hence, employers must work ever harder to retain highly skilled and valued employees. Employees have an ever-increasing desire for career growth and learning. Expanding educational opportunities for young engineers and the ability to cross-train are critical. This requires not only formal education through local universities and the short curse venue, but also intentional efforts to allow learning and growth on the job itself. This need is often intensified when the employer is unable to attract the employees with an adequate educational background. For example, as shown in Table 1, we at Sandia National Laboratories have a very difficult time attracting the talent needed as processing technologists in our Si-fab. The competition is intense and prospective employees have their choice of our fab or a number of commercial facilities in the Albuquerque area. The ideal potential employee would be one, for example, who has completed the Si-Processing Technologist Associates Degree program at Albuquerque's Technical-Vocational Institute (TVI). Other post high school education is of value, but the value varies as a function of the field of education.

Table 1

Si Processing Technologist
(Relative Training Metric – metric of time required to be self-sufficient)

TVI	10
BS-Chem	7
BS-Bio	4
BS-Arts	2
High School	1

A Bachelors of Science degree in chemistry is excellent preparation, while education in biology or the arts is of progressively less initial value. A bright high school graduate can certainly learn the required skills, but the learning curve is long and steep.

THE SHORT COURSE OPTION

Given then the need for continuing education, consider the available learning vehicles. Local universities provide an option, but the training requires a commitment of several hours each week for months and in many cases true hands-on industrial training is not part of the course. However, for training in more fundamental topics, the university option is likely the best. Training completely by on-the-job experience tends to be haphazard and inefficient. A third option is the short-course.

The short course format brings experienced real world instruction, is focussed and time efficient, is cost effective and generally compatible with a student's schedule. For many topics, it often times offers the opportunity to do "hands-on" learning, for example with access to a microscope or tester. Very significantly, short courses often draw students from a variety of industries and geographic locations creating the useful opportunity for cross-fertilization and networking.

The organization offering the course also receives benefit. For example, offering the course provides great exposure in the community. A successful program with large numbers of delighted students certainly lends credibility to the teaching institution in the topic of the course. In an emerging technology, the wide exposure given the institution solidifies their leadership position and often sets standards of practice as the technology develops. It also provides a mechanism to manage the interest of potential customers. Rather than try to inform large numbers of interested parties in an overwhelming number of one-on-one contacts, people can be encouraged to take the short course. This greatly minimizes the "public relations" burden from potential customers. Another very valuable benefit is that it can be an effective recruiting tool. Many times students become so interested in the work that they desire further involvement. If a university is offering the short course, the person may choose to take courses under the traditional curriculum or may even decide to apply for admission to a degree program. For other institutions, one may find talented individuals that can be recruited. There is an interesting downside, however, to the recruiting issue in that if a company is attempting to quickly build a program in a given area they may try to recruit from the organization offering the course. Finally, although certainly not insignificantly, teaching short courses can raise revenue.

THE PROVIDERS OF CONTINUING EDUCATION

A variety of institutions do in fact teach short courses. There are ample examples of universities, professional societies, not-for-profit institutions such as National Laboratories, and private companies all teaching short courses. The breadth of the courses taught by these institutions is quite extensive and can range from topics involving basic knowledge, to new emergent technologies, to the operation of equipment. This model is summarized in Figure 3.

	Basic Knowledge	New Technology	Equipment Operation
Universities			SEM
Professional Societies	Elements of Metallurgy		Fabrication Equipment
Non-Profits, Nat. Labs		MEMS	
Companies			IC Testing

Figure 3. Representation of institutions offering continuous education through the short course format and the breadth of educational material taught.

For illustrative purposes only, several of the matrix elements have been filled. It is important to realize that any one of the listed institutions can teach across the entire spectrum, but examples above are typical. General equipment operation, such as theory and practice of scanning electron microscopy, is well taught by universities, with perhaps the Lehigh University Short Course Program in electron microscopy being the best example. Professional societies, often using university faculty, commonly teach courses involving basic knowledge. The basic materials engineering courses taught by ASM International (a.k.a., American Society for Metals), perhaps being a good example. Similarly, ASM has a variety of courses on materials processing/fabrication and the associated facilities including thermal spray technology and heat-treating. Often, disruptive technologies emerge from National Laboratories or industrial laboratories. While the private firm is likely to choose protection of the technology for competitive purposes, the National Laboratory is likely to desire to release the technology in any way possible, including through the use of short courses. Finally, private firms, especially equipment vendors commonly teach short courses on the use of the equipment they sell into the marketplace.

Universities, equipment vendors and non-profit institutions like National Laboratories, often have extensive physical facilities, which can be used for hands-on instruction. While much rarer, professional societies may also have experimental facilities. For example, ASM has full state-of-the-art materials engineering education facility including extensive metallography, microscopy and mechanical test equipment. In some subject areas, access to hands-on facilities as part of training are of immeasurable value.

Micromachine Case Study

To illustrate the points described above, we will present an in depth case study of Sandia's experiences in developing a series of short courses in Micro-Electro-Mechanical Systems (MEMS). MEMS is an emerging technology, which uses Integrated Circuit manufacturing technologies to build microscopic machines. Applications of this technology are widespread, from ink-jet printers to a variety of automotive sensors. Sandia National Laboratories was an early leader of the development and maturation of this technology. The rapid growth of this field generated a number of challenges, both internal to Sandia, and throughout the industry. The first challenge was the difficulty in finding qualified employees to work in this rapidly expanding field. Mechanical Engineers did not have a sufficient understanding of integrated circuit manufacturing techniques, and electrical engineers did not have the necessary understanding of mechanical systems needed to impact the development of new devices. Training on the job proved to be haphazard at best, and few Universities offered formal MEMS curricula. The inability to find trained experts in this field proved to be a major impediment to the growth of the program.

In addition to the lack of trained specialists in the area, organizations also faced the challenge of dealing with the enormous customer interest. Organizations that were viewed as leaders were overwhelmed with requests for meetings to discuss potential applications of this technology. Supporting the interaction with external organizations proved to be a burden to a staff that was already stretched thin.

A third challenge that emerged was specifically associated with the design of MEMS devices. Sandia had made significant strides in developing mature MEMS technologies, but few people in the world had the background and knowledge to design new deices. This lack of qualified designers represented a bottleneck in realizing new products.

In order to address these challenges, Sandia chose to implement a series of short courses to train scientists and engineers in the field of MEMS. The first short course developed was an introduction to MEMS. This introductory short course provided training in how MEMS were built, what they were good for, and most importantly, how to design MEMS devices. The short course also included hands on training in testing MEMS devices, and use of MEMS CAD tools. At the end of the three day course, a student would have a firm understanding of the basics, and would be equipped to design simple MEMS devices.

Participation in the short course was facilitated by making registration possible by simply filling out a form online at our WEB site (www.mdl.sandia.gov/Micromachine). Because of the high traffic at this site, no other formal advertising was needed.

While the first short course provided a student with a solid background in MEMS, we soon learned that the short course did not provide enough detailed design information to allow students to design complex MEMS devices. To address this, we quickly introduced an advanced design short course. This course focussed solely on the issues of MEMS design, and had a prerequisite that a student first take the introductory short course.

These short courses have proven to be extremely successful, and have been a great benefit to both our organization, and the organizations sending participants. In the first year and a half, over 450 students took the short courses. At times, there has been as much as a six-month wait to gain admission into a class. Class size was limited to 20 students in order to encourage interaction.

Our organization has realized a number of benefits from developing these courses. First, it has helped reduce the burden of supporting potential customer interest, while at the same time improving our customer interaction. Instead of hosting a huge number of one-on-one meetings with external organizations, we encourage them to first take the short course. This helps screen the truly interested from those simply "fishing". Sponsoring the short courses has been an excellent customer development tool. When interested organizations take the class, they come away with a firm grasp of our capabilities, and are even trained to design in our unique MEMS

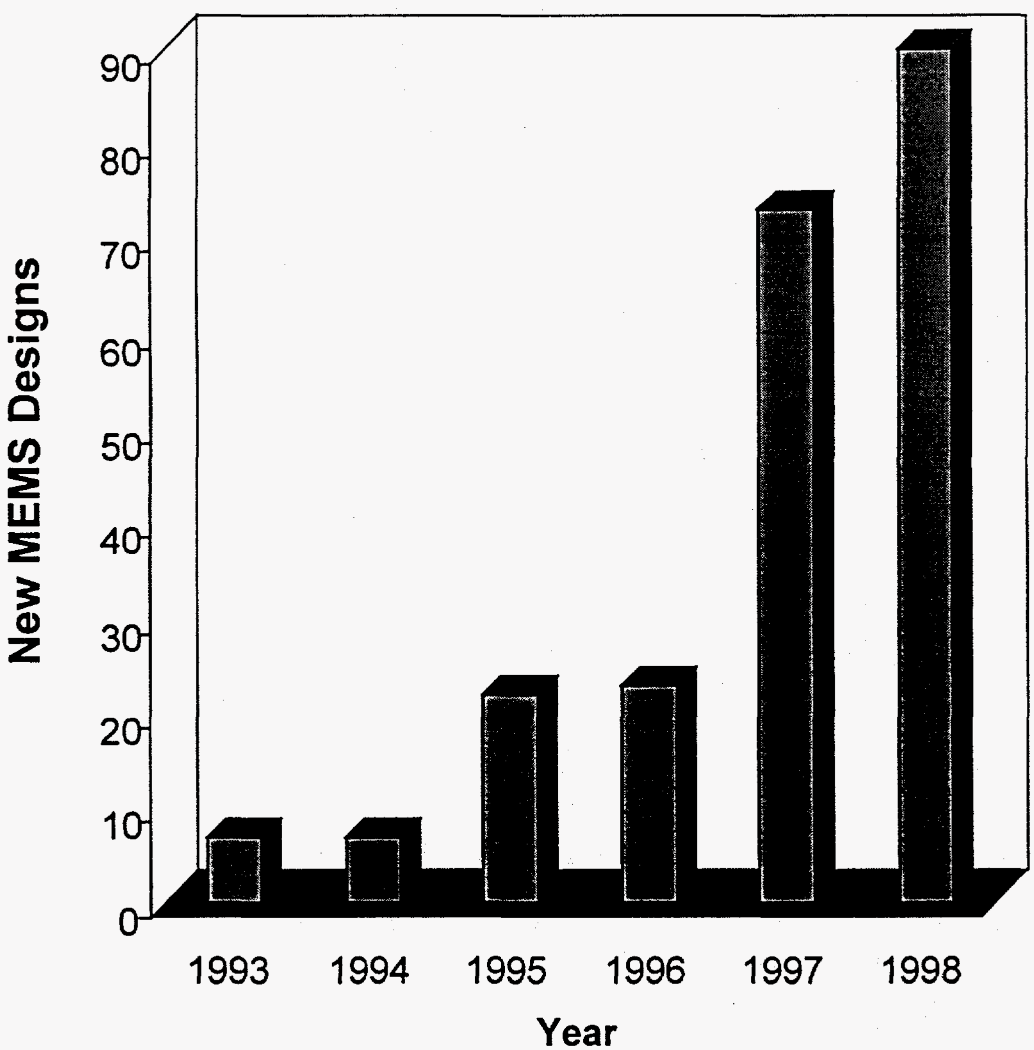

Figure 4. Sandia's MEMS program has grown as a result of the short courses.

technologies. The result of the short courses on our MEMS program is illustrated in Figure 4. The introductory short course was first offered in 1996. It can be seen that the number of new MEMS designs we fabricate has increased dramatically. All indications are that the growth will continue, and we estimate that in 1999 we will likely receive over 300 MEMS designs for fabrication in our facility. This dramatic increase in customers demonstrates the positive impact a short course can have on business development.

While new customers is the most important "bottom line" result of the short courses, there are a number of ancillary benefits. Offering a successful short course helps establish an organization as a recognized leader in a field. It helps to establish an organization's technology or capability as an industry standard, because it is the one that people understand. In addition they serve as an excellent networking tool. Many significant partnerships and collaborations have resulted from interactions that began with external participation in the courses. The short course has also turned out to be an excellent source of revenue, generating over half a million dollars to date.

With the success of these two initial short courses, plans are underway to greatly expand the courses we offer. This year, we will offer two additional classes. We have developed a course on MEMS reliability, and, in conjunction with Dr. Steve Walsh from the University of New Mexico, we will be offering a course on the management of disruptive technologies. In the future, we plan to further expand, and offer courses on topics such as radiation hardened microelectronics, packaging, sensors, and optoelectronics. We are also beginning to investigate the possibility of offering a WEB based version of the class for organizations with tight travel budgets. As WEB based collaborative environments mature, we believe that WEB based participation in the class will become practical.

Critical Issues for the 21st Century

With rapid advances in Technology, our view of the educational process must change. As discussed previously, the drivers of this change include an ever quickening pace of technology advances, new "disruptive" technologies, a dynamic workforce characterized by less job security and less loyalty in the workforce, and less room for technically obsolete workers. Educational opportunities are one mechanism to better equip employees and employers to cope with these changes. Given the advantages of the short course option, it will become increasingly important. With increasing importance and value, the rigor of the educational format must increase. Anticipated changes involve accreditation of short courses, pre-requisites for participation, the testing for participants and certification of graduates.

The increased rigor of short course education will also bring the evolution of short course curricula. These curricula, as illustrated in Figure 5, will be created as a series of "modules." Modules will be sequenced in several ways. One sequence will educate in depth; one in breadth and, in combination, potentially leading to a "certified" individual through an accredited program. As discussed above, the MEMS sequence illustrated in Figure 5 has already been implemented in Sandia's MEMS curricula.

Of course, issues such as who is responsible for "accreditation" and how you validate the "certification" are questions yet to be answered.

The ways in which education will be offered in the 21st century is also undergoing radical change. There is no reason to expect that the same is not true of the short course format. The widespread use of information technology is likely to be the most dramatic change. Web and CD based short courses will continue to grow in popularity, although this is probably best viewed as replacement for current home study courses as opposed to the short course as used in the context of this paper. Web-based, tele-present learning will also emerge. This should offer most of the advantages of the traditional short course venue, but person-to-person networking is greatly reduced. In most cases, hands-on training will also diminish, but remote operation of equipment and remote access to computers, for design for example, are certainly possible.

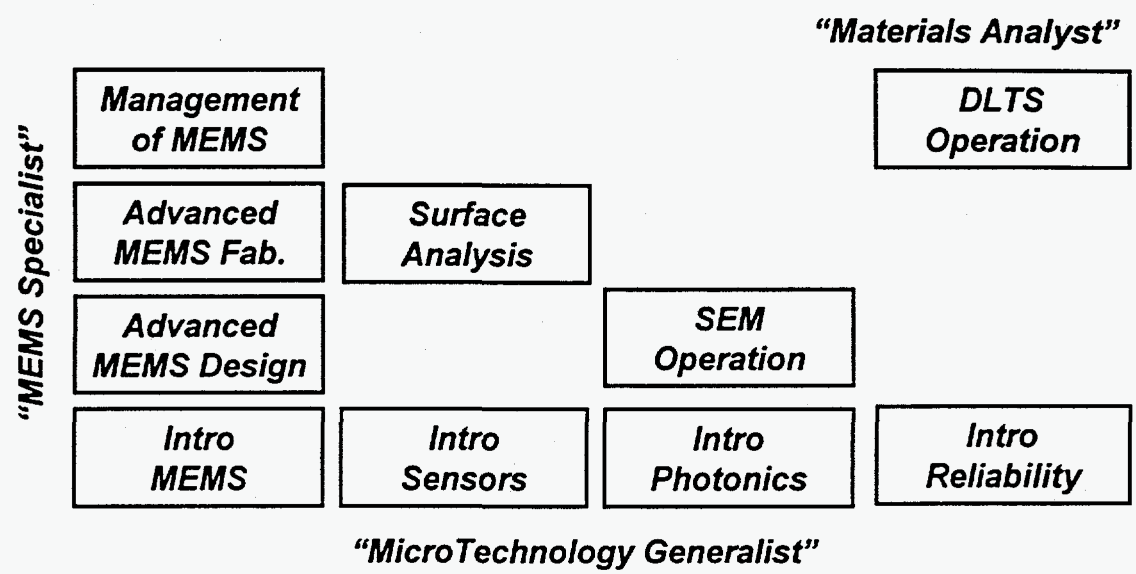

Figure 5. Illustration of assembling short courses into modules to create curricula which train in depth, breadth, or in combination potentially creating a curricula leading to accreditation of programs and certification of individuals.

Very importantly, there are a number of activities, which might naturally follow-on from the short course. Access to user facilities in which former students might have access to the facilities at the institution is already a common follow-on. While today much of that access is via personal presence, remote use through interactive tools will become increasingly important. For example, in our own MEMS short course program, students have access to the design facility and Si foundry through personal or remote access to our CAD tools. Finally, as mentioned previously, the creation of accredited programs leading to certification of individuals is another follow-on, especially in areas where it is not possible to receive such certification though traditional higher education vehicles.

SUMMARY

The relentless pace of change and technological innovation will continue at an ever-increasing pace. Continued, life-long learning will become increasingly more important as a result - important to both the employee and to the employer. Competitive companies must allow their employees to take courses and they must also offer courses within their competencies (within the framework allowed by the protection of intellectual property). As the value of this educational venue becomes more and more widespread, there will be increasing pressure to accredit programs and ultimately certify individuals. While the importance and value of personal educational experiences on site will never disappear, the value of education via modern information technology will be of growing importance.

References

1. J. L. Bower and C. M. Christensen, *Harvard Business Review*, January-February 1995, page 43.