

Introducing Industrial Organizational Training into an Interdisciplinary Engineering/Science Graduate Program

Ken Vickers, Greg Salamo
University of Arkansas

Abstract

This paper describes a new interdisciplinary graduate program between science and engineering implemented at the University of Arkansas in the fall semester of 1998. This graduate program in Microelectronics-Photonics (microEP) supplements the traditional education elements of coursework and research with non-traditional training and within-program implementation of industrial operational practices. The non-traditional training is based in the methodology that microEP students operate in an industry-like dual-reporting scheme, being supervised by both their major research professor and the microEP program director. Under the program director, the students are grouped by entry year into cohorts that manage their joint education as if it were the expected output of an industrial factory. This paper will provide an overview of the major goals of the program, the specific activities that have been implemented to meet these goals, and an evaluation of the program's effectiveness after three semesters of operation.

I. Introduction

The education and training of the workforce necessary for global competitiveness of American industry in high technology areas, along with the proper role of academe, government, and industry in that educational process, is being examined in widely divergent industrial segments. Academic areas such as manufacturing engineering, aerospace engineering, and electrical engineering have all reported results from such studies [1-5]. These reports reveal several broad themes of educational need developing across these industrial segments:

- a) Integrating technical and non-technical broad knowledge areas.
- b) Integrating multidisciplinary technical skills into a comprehensive knowledge base.
- c) Integrating global perspectives into local decision making.
- d) Integrating soft skill set development with traditional technical education.

It is our intent to address these broad themes at the University of Arkansas through an innovative combination of traditional coursework with an industry-like work environment, which is then overlaid on state-of-the-art research in high performance microelectronic-photonic materials,

devices, and systems. The training required to master these four themes will be integrated into each student's academic curriculum and research efforts.

In June 1997, Dr. Greg Salamo at the University of Arkansas received grants from the National Science Foundation EPSCoR Program (NSF) and the Arkansas Science and Technology Authority (ASTA) to create an interdisciplinary research center between engineering and science to pursue work in ultra-fast electronic-photonic devices and systems. The grant was designed to financially support five post-docs and 13 masters students working in this area; to financially support junior research faculty members; to provide a moderate amount of per-student funding for equipment and materials; and to financially support the center director for two years.

This grant resulted in the formation of the Arkansas Center for Electronic-photonic Materials Innovation (ACEMI) in early 1998 under the leadership of Dr. Salamo and Center Director, Ken Vickers (Texas Instruments, Sherman Wafer Fab engineering manager from 1991 – 1998). Faculty participants in the Center were already working in the research areas of interest to the center, and included faculty from the Physics, Chemistry, Electrical Engineering, Chemical Engineering, and Mechanical Engineering departments.

One critical deliverable included in the proposal was the creation of a rigorous research-based interdisciplinary graduate program that would attract students from many technical backgrounds. The program would act as a virtual department, utilizing existing traditional department educational strengths while supplementing them with operational skills training supplied by the Center's director. This interdisciplinary graduate program recruited its first students in the fall of 1998, defined and implemented the Master of Science in Microelectronics-Photonics (microEP) in fall 1999, and has submitted the Ph.D. in Microelectronics-Photonics into the approval process for implementation in May 2000.

These degree programs are designed to give their graduates not only state-of-the art research training and deep level subject knowledge, but also provide them with the soft skills necessary to efficiently utilize their knowledge early in their professional careers. Unique elements of the program created to support these design objectives include:

- a) An interdisciplinary curriculum of applied physics and chemistry courses, as well as engineering courses from multiple departments.
- b) Students grouped together as a pseudo-industry engineering group, with each student reporting both to their research professor and to the microEP director.
- c) A student requirement to become proficient in a standard software suite (word processing, spreadsheet, electronic communications methods, project management, etc).
- d) Expedited student placement with faculty for research to assure maximum exposure to research during the master's program.
- e) Assigned student responsibility to manage some aspect of group interests (class schedule coordination, seminar selection, software management, etc).
- f) Multi-day industrial style training seminars in structured innovation processes and processes to promote inventiveness.

The intent of the program is to prepare the students for faster acclimation and initial success in any industry-like environment upon graduation. By creating an environment where students support each other in classes and research outside their academic background field, they learn how to reach a common goal a part of a diverse team. They view the success of all the group's members as important as their own individual success.

This talk will present the activities implemented at program start-up, with a discussion of effectiveness of each activity after completion of the first three semesters of operation.

II. Student recruitment

The program was initiated late in the spring 98 recruiting season, forcing the recruiting effort to be concentrated on on-campus and in-state student populations. Presentations were made at all meetings of relevant student organization on-campus, and visits and phone calls were made to other in-state institutions.

Students that displayed an interest in the program were then extensively interviewed by the program director. The interview was designed to understand (1) did the student's academic and career interests match the microEP research goals and (2) did the student's personal life goals match the lifestyle choices that would result from a job in this academic area. Only after the student and the director reached agreement on the program being a good match to the student's academic and lifestyle goals would the interview continue to the academic evaluation of the student.

We have found that this intense interview process is critical to student success, as the student becomes the explicit owner of the decision to embark on this difficult curriculum in pursuit of his own career and lifestyle goals. We plan to continue using this interview technique to screen program applicants, and anticipate that we will continue to lose some top academic applicants to this interview process. But early feedback from students completing their first year in the program indicate that we will lose only a minimum number of students to program dissatisfaction, educational failure, or changing career objectives.

This interview process has not limited the applicants to the program, and the students currently enrolled in the program demonstrate the technique is not limiting the student population's diversity. In its first year, the program attracted 12 students from the USA, Spain, Malaysia, China, Pakistan, Honduras, and Trinidad. Of this group, there was one African-American student, four Asian students, one Latino/a-American student, five Caucasian students, and one Middle-Eastern student. Three of the students were female. In the fall of 1999, twelve additional students have been attracted to the program. In this second year group there are three African-American students, one Asian student, two Middle-Eastern students, and five Caucasian students. Two of the students are female.

This initial program enrollment of twenty-four students, with 21% female and 16% African-American, creates a core student group to act as a recruiting resource that allows students from minority and underrepresented groups to see demonstrated success by their peers in the program. The ability of student applicants to see "proof-of-concept" success while visiting our campus or

examining program documentation will be a significant factor in a future recruited student's decision to enroll on our campus.

Student recruitment continues to be a high priority to the microEP program management team, as the University of Arkansas was awarded a 1999 NSF IGERT (<http://www.nsf.gov/igert>) award to support Ph.D. students in the microEP program. This proposal is expected to support approximately 18 microEP Ph.D. candidates for three years each over the next five years.

III. Curriculum definition and course prerequisites

The microEP curriculum was created to support both students interested in a terminal MS degree as well students interested in completing a Ph.D. in microEP. The microEP program is viewed as a professional development type graduate program, with the clear intention of allowing students the needed flexibility in a graduate program to optimize their education for success in this broad industrial field.

In designing the model curriculum for the microEP program, the published results of industry working groups were examined. From the large industry perspective, the need for a broadened knowledge base in their scientists and engineers lies in the broad financial impact of the decisions they will make. In a survey of manufacturing engineering jobs, Mason reports that "The results... also emphasize the importance of a broad education. Engineers need to be technically proficient at their job and at the same time understand the economic and engineering implications of their decisions." [4]. The Boeing Company CEO Philip Condit has stated that "... it is important that engineering education also have breadth. Students need to know about business economics: What does it cost to build a project? What's involved in integration?" [6].

On the other end of the business size spectrum, small entrepreneurial technology startups are requiring their smaller employee base to not only develop the technology, but also to manufacture and market it. Robert Morgan has reported the results of a meeting of fifty leaders of the National Academy of Engineering (NAE) that "Engineering employment in manufacturing has moved somewhat from large companies to medium and smaller ones, including many start-up businesses. These workforce changes have created a demand for engineers who can fuse technical, managerial, financial, and industrial skills." [5] The same attendees noted that future technologists "... need a breadth of knowledge to handle complex objectives and multidisciplinary functions, to understand non-engineering issues, and to perform systems engineering in a loosely bound environment".

Courses were selected for the model microEP MS degree curriculum based on (1) their support of the research objectives of the center or (2) their nature as stand-alone "toolbox" courses to teach specific business or technical skills. The microEP program curriculum concentrates on application courses that would apply to high technology industry, on courses that present the introductory theory behind the applications, and on a business course that introduces the student to the decision processes encountered while taking a research idea to market.

Theory courses included an EE solid state device course, as well as laser and non-linear physics courses. Applications courses included an EE course in integrated circuit processing, a ME course in electronics packaging, and a chemistry course in surface instrumental analysis. The

preferred business course has been developed specifically for the microEP program, and will be team team-taught by the program director and a business administration professor. This course will concentrate on the decision processes involved with the intra and entrepreneurship of state-of-the-art research and its potential for commercialization.

Students may enter the microEP graduate program from any rigorous BS or MS engineering or science program, with undergraduate course deficiencies being limited only to the courses required to assure their success in graduate courses of interest. This effectively requires physics through junior level introduction to quantum mechanics and mathematics through differential equations. Students entering the program may have to correct other course-specific deficiencies, but are not required to take a departmental based undergraduate deficiency curriculum.

Instructors have been supportive of the students from other degree programs that may not have as strong a background as BS students from their own department. We have also found that the microEP students with more applicable educational backgrounds for a course are very supportive in a tutorial fashion to their colleagues from other degree programs. We plan to continue to encourage microEP students to apply themselves to stretch their boundaries into new areas, just as they must do in a professional career setting.

Students entering the microEP program after completing a MS degree in another field are expected to use Ph.D. required course hours to accomplish the same type of curriculum breadth achieved by the model MS microEP curriculum. Ph.D. applicants are allowed to enter the microEP program by taking the qualifying exam from the UA Ph.D. program matching their MS degree, or they may take the microEP qualifying exam after completing a core of microEP related courses.

At this time, the program includes eleven students planning to exit after completion of their MS degrees. Nine students are working on their MS degree but are planning to continue their education for a Ph.D. microEP. The remaining four students have already completed a MS degree in either physics or engineering, and began a Ph.D. course of study in the fall 1999 semester in anticipation of the successful approval of the Ph.D. microEP in the spring semester 2000.

IV. Pseudo-industry engineering group management

It is impossible for students to become a deep level expert in all technical areas. It is possible for students in a flexible graduate program to selectively pick academic courses from outside their background undergraduate degree that will provide them with the ability to work intelligently with specialists from other areas. Joseph Bordogna, past deputy director and chief executive officer of NSF and president of IEEE, has stated “cross-functional collaboration and multidisciplinary problem-solving, insofar as they tap individual creativity and enhance the range and quality of solutions, have grown equally essential to the success of the R&D effort (as technical skills).” [7].

Successful collaborations require a student to have effective skills outside of academic training, and this has become of prime interest to prospective employers. These outside soft skills

encompass everything from management-related skills such as project management and supervisory skills, to interpersonal skills such as effective communication and team problem solving.

Betty White, The Boeing Company's director of engineering and technology support and university relations has said "We need engineering graduates with a broader perspective. Beyond discipline-specific needs, our engineers need communication skills, the ability to work in teams and to understand design and manufacturing processes, and a basic understanding of the context in which engineering is practiced" [8].

A key experimental educational method in the microEP graduate program is putting the program director in the roll of manager of a technology/engineering group in industry. The technologists reporting to him are the microEP students, and the industry they are supporting is the "educational factory" that is producing technically trained graduates (themselves). Each student must meet the program director's requirements for developing industrial soft skills as well as their major professor's requirements for meeting their research goals.

The microEP requirements include weekly operational meetings to provide a forum for open group discussions. Discussions include cultural issues such as comparisons of home country culture to US culture, discussions of current interactions between technology and society, and professional ethics. Educational issues are included, such as group overviews of individual curriculum choices as well as research discussions with microEP faculty. Some sessions are also used to discuss the most efficient usage of software tools for such things as creation and management of their educational path in Microsoft Project.

The intent of this methodology is to bring this diverse group of students rapidly together to form a group identity that nurtures the success of each student within the group. The students will travel as a cohort though their educational process, with a new cohort forming each year made up of the new students entering the program during that academic year. The members of each cohort are provided the opportunity to practice the cross-functional collaboration proposed by Bordogna through collaborative study in course areas outside of their undergraduate expertise, and through research collaborations with groups in multiple traditional departments.

This is a significantly different concept than the traditional research group under one professor. Students in a traditional research group will be at vastly different research skill levels, taking much different courses, and will lack connectivity with students other than those in their own research area. The pseudo-industry engineering workgroup concept is supplementary to the traditional research group, and gives the student a focused opportunity to practice the teaming skills so necessary in today's high technology industry.

We have found this organizational to be very successful, but the transportability of the concept is somewhat dependent on having a director that is experienced in engineering group management in the industrial environment.

V. Office suite software proficiency requirements

All microEP students are required to become proficient in using a standard office software suite in meeting their coursework, research, and microEP documentation requirements. This includes word processing, spreadsheet, electronic communications methods, project management, and presentation software. They are also required to learn touch-typing and be able to demonstrate forty word-per-minute typing rates on normal text documents.

The intent of this tactic is to force practice opportunities on the students that make them become aware of the capabilities of these commercially available productivity tools. While none of the tools are a pre-requisite to success in the workplace, they certainly prevent the student from having to spend critical early workplace training time on communication methods.

We feel these skills are critical for early workplace success of our students, and we have included these requirements in the course catalog degree description.

VI. Matching of student and research faculty member

Matching of each microEP student to a research faculty member is based on several items. One is the interest and ability of the faculty member to handle an additional student. The second is the matching of the student's interests with the research field of the professor. A third is the need to place the student into a research environment as soon as possible. And the fourth is the interest in placing each student with a professor outside of the student's undergraduate degree field.

The microEP program director manages the process, arranging interviews between each entering student and the three faculty members that would best meet the multiple goals of a student/research professor team. The student selects his top choice after the interviews are completed, and if accepted by that research professor, will begin working in that lab for a 60-day trial period. At the end of the trial period, either party can cancel the relationship without bias or they can agree to work together for the student's research project. A trial period can not be extended.

Once a student is teamed with a professor, the student has an obligation to complete a research contract with his thesis committee within three months. This document describes the background to the research (abstract), the research to be performed, and the minimum research output necessary to meet graduation requirements. This document is designed to force research project management on all parties involved in the student's education, and to assure that all parties involved expect the research to be completed as defined within a two year period.

The trial assignment process has had mixed results. It has been successful in moving students quickly into a research environment for learning purposes. Yet only half of the first cohort are completing a MS research project under their originally selected research professor. This subject is under review by the microEP management team at this time to learn from the first cohort's experiences, but no operational changes have been identified at this time.

The research document process has also had mixed results. Requiring the student to create the document has forced critical thinking of research objectives early in the student's graduate work.

But we have found that the research documents are difficult to complete in the three-month time target time period, as the graduate education system's culture is not strongly aligned with the concept of project management. We have also found that research personnel typically do not wish to support a final research objective until late in the student's planned educational period.

The microEP management team feels that an early research document has significant merit as an early visualization tool for the student, and forces early attention on the need for a linear approach to their research. It is apparent that this document must retain a significant amount of flexibility to allow objective realignments during the course of a student's education, while still maintaining the benefit of long term project planning. It is expected that this document will be merged with the project management software requirement, which would benefit both the research management task and the student's proficiency in usage of the project management software.

VII. Student management of group interests

One particular teaming skill that is critical to modern workplace success is the concept that no student is successful unless all students are achieving their own maximum performance. Or in other words, individual success and achievement is critical and necessary, but does not matter if the group fails in its overall objective.

Each microEP student is assigned an area of responsibility on an ad-hoc basis to support group needs as they are identified. Areas that have been identified to date include web page creation and maintenance, class schedule negotiations with departmental coordinators, seminar selection and notification, software management, electronic communication maintenance, etc.

A student assigned to such a task is expected to become the expert on that area, and to support the other students' needs in that area. Our experience has been that when a group need is identified there is a burst of activity required by the student manager, followed by a low level of background maintenance activity.

We expect to continue using this tactic to teach responsibility to the group, as well as to give the students an opportunity for practice in group-dynamics management when other students do not fulfill their assigned rolls.

VIII. Invention and innovation training

Traditional technical graduate programs assume that the students that advance to graduate school in these disciplines have a high degree of inventiveness, both by natural skill and through skills learned in their undergraduate curriculum. While there is a basis for this assumption, the natural skills in these areas have been far from fully developed by typical undergraduate curricula.

The microEP program attempts both to develop the inventiveness and innovation skills in the students and to train them to use these skills in every stage of their education. They are encouraged to apply a heightened innovation effort to normal classroom behavior, their laboratory practices, and even their everyday non-technical pursuits.

Seminars have been scheduled on inventiveness from such authorities as Dr. Ed Sobey (creator of the Kids Invent Toys (TM) program and past director of National Inventors Hall of Fame) and on structured innovation from Dr. Gerard Puccio (Director of the Center for Creative Studies at Buffalo State College). Further resources on invention and innovation are imported to the program through the National Collegiate Inventors and Innovators Alliance (www.nciia.org).

We expect that this effort to actively train students in alternative thinking patterns will be a major factor in improving their creative success in both their education and their careers.

IX. Conclusions

The intent of our microEP graduate program is to prepare our students for faster acclimation and initial success in a high technology teaming environment upon graduation. By creating an on-campus environment where students support each other in classes and research outside their BS academic field, they learn how to reach a common goal a part of a diverse team. They view the success of all the group's members as important as their own individual success.

The educational tactics that have been developed in the microEP graduate program over these three semesters have acted as a whole to create a successful MS graduate program. They have been expanded to embrace the Ph.D. microEP students that began their degree programs at the University of Arkansas in the fall semester 1999. We expect both degree programs to flourish and lead the way into developing the interdisciplinary educational techniques that will assure the success of the University of Arkansas in the coming decades.

The current status of the Microelectronics-Photonics Graduate Program at the University of Arkansas may be found by visiting the program web site at <http://www.uark.edu/depts/microep>.

X. Acknowledgments

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KEN VICKERS

Ken Vickers is a Research Professor in Physics at the University of Arkansas, and has served as Director of the interdisciplinary Microelectronics-Photonics Graduate Program since April 1998. He worked for Texas Instruments from 1977 through March 1998 in integrated circuit fabrication engineering, the last seven years as Engineering Manager of the TI Sherman IC Wafer Fab. Ken's technical accomplishments before leaving TI included chairmanship of the Sherman Site Technical Council for six years, election to Senior Member Technical Staff, chairmanship of two corporate level worldwide teams, and authorship of twenty-four issued patents. He received BS and MS degrees in Physics from the University of Arkansas in 1976 and 1978 respectively.

GREG SALAMO

Greg Salamo is a University Professor of Physics at the University of Arkansas. He leads several interdisciplinary research efforts between universities and industry in photonic materials and semiconductor nanoscience, and has been the leader at the University of Arkansas in promoting interdisciplinary research and education. Dr. Salamo received a BS degree in Physics from Brooklyn College in 1966, an MS degree in Solid State from Purdue University in 1968, and his Ph.D. in Optics from CUNY/Bell Labs in 1973. After a Post-Doc position at the University of Rochester, he joined the faculty of the University of Arkansas in 1975.