2006-1701: EMBEDDING THEORY AND PRACTICE OF TECHNOLOGY GROUP MANAGEMENT IN AN INTERDISCIPLINARY SCIENCE/ENGINEERING GRADUATE PROGRAM

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Embedding Theory and Practice of Technology Group Management in an Interdisciplinary Science/Engineering Graduate Program

Background

In 1998 there was a positive atmosphere in support of interdisciplinary graduate programs at the University of Arkansas by the central administration, with leadership being provided by the new Chancellor, Dr. John White. One interdisciplinary graduate program had already been created in Environmental Dynamics, although that program only spanned departments within the Fulbright College of Arts and Scientists.

Faculty in multiple science and engineering departments were working in many research areas in micro technology, and there were strong developmental areas in several fields of nanotechnology. The primary research thrusts in these areas, along with the associated educational coursework, were in electronically and photonically active materials, the devices that could be made from these materials and the high performance subsystems that could be made through a combination of these materials and devices.

This research was by its very nature interdisciplinary, with the separation between science and engineering blurring at the micro scale and disappearing at the nanoscale. This created natural partnerships across departmental boundaries between individual faculty members and small research groups. What was lacking to the faculty working in these turbulent boundaries between traditional departmental emphases was a method by which their students could optimize their curriculum in support of their career preparation. Their students had no method to take career-based coursework from different departments – and still be granted a degree at the end of their educational path as a graduate student.

In 1998 a position was created using a combination of National Science Foundation (NSF) and University funds to hire a technical manager from industry to establish and promote an interdisciplinary graduate program in support of the research faculty in this area. Ken Vickers was hired into this position after twenty years at Texas Instruments in integrated circuit process and equipment engineering. The charge was to incorporate industrial management methods into both the program's internal management, and into the student curriculum using both formal and informal methods.

The stated goal of this experimental approach to graduate education was to create a MS/PhD program that emulated an industrial work group environment in a traditional academic setting. The approach was to define to the student participants that they now not only had individual achievement goals, but also had a group goal to assure that every graduate student achieved the highest level of career preparation of which he or she was capable.

The interdisciplinary science/engineering graduate program in Microelectronics-Photonics (microEP) was created at the University of Arkansas in the fall of 1998 under Vickers' guidance to merge traditional graduate research and educational excellence with specific training in operational effectiveness methods, intra and entrepreneurial skills, and teaming and group

dynamics practice. The primary traditional departments that were partnered in this effort included Electrical Engineering, Mechanical Engineering, Chemical Engineering, Physics, Chemistry, and Management.

This educational experiment was supported initially by a NSF small group research grant, followed by a 1999 NSF Integrative Graduate Education and Research Training (IGERT) grant and a 2000 Department of Education Fund for Improvement of Post Secondary Education (FIPSE) grant. The microEP program has since won a three year NSF Research Experience for Undergraduate (REU) site and then five year extension, a five year NSF Graduate Student in K-12 Education (GK-12) grant and then five year extension, a NSF Partnership for Innovation (PFI) grant and then follow up PFI grant, and a five year NSF Material Research Center for Science and Engineering Center (MRSEC) grant with a just awarded second five year continuation.

The specific elements for microEP students' career preparation were (1) academic excellence in courses that would directly support a student's professional performance, (2) research excellence in an area that would provide practice of the academic knowledge being gained through coursework, and (3) operational excellence in both the execution of graduate research and in management skills needed in early professional careers.

This paper will not address the first two elements of the microEP Graduate Program, but will instead concentrate on the third element. Methods will be discussed that have been used to address this aspect of the microEP educational goals, including both the early activities that were significant failures and some recent approaches that are being significant successes. A complete overview of the microEP Graduate Program after five years may be found in a prior ASEE annual meeting publication[1].

Management practices in the UA academic environment

The microEP grad program was created with a core value of giving its students both the theory and practice of managing professional academic and/or industrial technologist groups. It was expected that the theory portion of management education would have significant educational resources available from which to choose, but the practice of management in the academic setting would be difficult.

First, it was recognized early in the program planning that the professional behaviors observed by UA students during their undergraduate/graduate careers are overwhelmingly academic in nature. As in every profession, current academic professional behaviors have developed over the last fifty years under the influence of the academic reward and recognition systems that have grown over that same time period. The rewards to faculty at the UA are similar to typical systems in PhD granting institutions, in that they focus on tenure and promotion with a large element of the assessment function concentrated on research attainment and publication.

Even with an increased emphasis from US national funding agencies on collaborative research efforts, most of the UA research proposals in 1998 originated from individual researchers or from small research groups. There was very little coordination between UA faculty members to

build different areas of research "critical mass" that would support success of future research proposals by other faculty.

Second, while the academic departments' management methods were not discussed with its students – it was apparent to the students that organizational efficiency was not a hallmark of academic departments. The observed interactions between faculty members were minimally supportive at best, bordered on professional indifference most of the time, and were even on occasion openly antagonistic with no observed repercussions.

At the same time, at least the engineering departments' students were seeing their curriculum change in order to meet new ABET requirements that stressed such things as teamwork, open communications, conflict management and resolution, and organizational coordination toward common goals. Even the students in science departments were reading of the need for soft skills development in their student society publications, although that need was not being translated into a national standard effort in curriculum modification.

The microEP management team was faced with the problem that all entering students would have spent typically the last four years directly observing professional behaviors that were optimized for an academic environment created directly after World War II. Unfortunately, most science/engineering grad students enter positions in industry (or other large industry-like organizations with well defined group goals such as national labs) after graduation, not academics. In these industry-like organizations, academic professional behaviors would not only be a detriment to career success – but could even result in job termination if taken to the extreme (see Table 1 for illustrative examples directly observed by Vickers after his transition from industry to academe).

Table 1: Illustrative Examples of Professional Behavior Differences between Industrial and Academic Environments

Practice	Industrial Environment Behavior	Academic Environment Behavior
Job goal alignment	Management defined to support group goals	Individual voluntary alignment to departmental efforts
Creative work	Balanced between management assigned tasks and self defined tasks	Self defined, with possible voluntary collaborations on large projects.
Work hours	Coordinated to optimize group performance	Self scheduled to meet personal goals and institutional assignments
Work location	All work at common location to support ad-hoc work groups	Independently set hours at home and campus to meet personal needs (and office hours).
Compensation system	Rewards group performance, then individual contribution	Rewards individual accomplishments, not departmental success
Problem solving	Collaboration is necessary for success and is strongly coordinated across groups	Collaborations are theme based voluntary coordination of individual research projects

It should be noted that the comparisons made in Table 1 do not indicate that one set of behaviors is superior to the other, but the comparisons do indicate that the two systems of behaviors are significantly different from each other. The problem faced by the microEP Graduate Program was to first educate its students in understanding the expectations of performance in different professional environments, and then to give them the opportunity to practice industrial management skills in the confines of an academic environment.

Methods used in management skills training

The microEP management team initiated the program by establishing some standard industrial methods for group organization and communication among the eleven students entering as Cohort 1 in the fall semester of 1998. These included:

- Weekly group meetings for coordination between students
- Weekly written reports for communication of accomplishments, problems, and plans
- Every semester resume updates
- Every semester research plan updates
- Every semester curriculum advising

The format of the weekly meetings was open, but generally followed a pattern of asking each student for an oral summary of the contents of their prior weekly reports. Discussion was encouraged between students on what resources, strategies, or tactics could be applied to the problems being reported, and Vickers would also add to the discussion insights gained from facing similar situations in industry.

One unexpected aspect of these requirements was pushback from some students' research faculty that the microEP program management was being too intrusive into the traditional mentoring relationship between a professor and their student. There were times when the student would receive input from Cohort colleagues, Cohort management, and the Major Professor that went beyond lack of alignment into strong opposition.

This was especially true in the curriculum advising arena, where a two part advising process was implemented. The student would first review and modify their desired curriculum, the Cohort manager would review the curriculum and offer feedback, and then would certify that the final curriculum would meet all boundary conditions for degree completion. The student would then take that certified curriculum to their Major Professor for review and discussion, would modify it if needed after that input, and would pass it back by the Cohort Manager for degree certification if modified.

The key new cultural element introduced in this process was the explicit statement that the student was the final authority on curriculum decisions, not the Major Professor. This single element began the process by which the relationship culture between faculty members and graduated students began to change from being a supervisor/employee relationship to a true partnership relationship between professional colleagues of different knowledge and experience levels.

It should be noted that after the first year, the microEP students strongly suggested that the weekly meetings be formalized with specific educational elements each week in management techniques instead of just being a status update meeting. In response to this input, starting with Cohort 2 in the fall 1999 semester, specific readings were assigned weekly from the book "The Human Side of Managing Technological Innovation" by Ralph Katz (now in its second edition). These readings are generally followed, although significant campus or community events that illustrate topics in management are sometimes substituted at the last minute in order to use them as emerging case studies that directly affect the student's environment.

By the fall of 2000, the first PhD students were approaching the point for their candidacy exam to be admitted fully as PhD candidates. Examining the engineering and science departments' candidacy processes on campus showed variations to a common theme, with that them being a series of closed resource tests on specific course-based subject matter. In effect, the students were studying for and taking a series of final examinations of various core courses in each department.

While there are certainly benefits to this approach, the faculty did note that the results of the exam were sometimes at odds with the observations of a student's performance in "PhD-like activities", and that studying for the exam was a significant disruption to the students' research for up to one year in advance of the examination.

The microEP Graduate Program defined a new approach to its written candidacy examination, with the following design criteria:

- The exam would be an evaluation instrument of PhD-level professional behaviors rather than a content test
- The exam would be defined such that no student would benefit from cramming specific knowledge prior to the exam
- The exam would require significant self-management of resources and significant creativity
- The student would enter the exam without a clear understanding of their chance for success from the microEP management team

In other words, the exam would not be used as a deliberate wash-out mechanism if at all possible. Students would receive significant career counseling leading up to the candidacy examination, such that any student whose professional behaviors in their graduate academic and research performance is below the PhD learning curve would be clearly counseled of the risks of continuing in the PhD path and encouraged to create a successful professional life with completion of the MS degree.

The examination is now in its sixth year, and past examinations are available on the microEP web site for examination (http://microEP.uark.edu, Documents, Past PhD Candidacy Exams). The examinations have elements of a research solicitation and elements of an industrial request for quotation. The students are issued the exams on the Friday before spring break, they have full access to any written source materials over the spring break week (but no conversations with

any person about the exam), and they must limit their response to fifteen pages and return their solution by noon of the Monday after spring break.

The exam describes a complex problem to be solved. The solution must describe the science supporting the solution, the engineering application of the science, an analysis of manufacturing costs and issues, a discussion of the intellectual property issues, an the impact of their solution on the environment and society. The solutions are reviewed in a NSF panel-like format, as each student's solution is absolutely unique.

This method has proven to effectively meet the design criteria, even though it is a much more difficult process to implement from a faculty perspective. Students that do not clearly have a complete solution may be given the opportunity to expand their approach in an oral exam. Students that do not pass with or without an oral exam receive extensive debriefing on the strengths and weaknesses in their approach as identified by panel members, which results in specific professional development plans that must take place over the next year before they take the exam for the second and final time.

A second part of the candidacy exam is a detailed PhD research project plan that is once again limited to a fifteen page document. This project plan is presented to the student's committee and the microEP community early in the research path in order to give the student feedback on ways in which the project needs to be expanded, focused, or modified. Once again, the purpose is to strengthen the student's research planning and management skills – not to eliminate the student from the program.

This microEP approach to the candidacy process is now well understood across the traditional science/engineering departments because of the wide number of departments represented by the microEP faculty group. Even though the benefits of this approach to the students have been widely discussed, no traditional department has abandoned their historical approach of a course final test and moved toward this style evaluation instrument.

Other methods to introduce management training have been introduced in the eight years of the microEP Graduate Program's existence, with varying degrees of longevity and acceptance by faculty and students. The most interesting examples include:

- MicroEP infrastructure management by students
- Annual event ownership by all Cohorts
- Monthly industrial-style student research presentations
- Formal research planning using Microsoft Project ™
- Weekly student-led research mentoring group sessions

The attempts to create opportunities for student management practice through having responsibilities for either the infrastructure needs of the microEP Graduate Program (i.e. software management, computer repair, communication infrastructure, and meeting scheduling) or through accepting student ownership of an annual event (i.e. undergraduate research conference) were total failures. There was insufficient student continuity, faculty support, and

institutional memory to support these activities. While the potential benefits were significant, these efforts were abandoned after one year each.

Student research presentations are elements of many programs, and the microEP Graduate Program was no different in that monthly all-microEP meetings were scheduled specifically for student research presentations. These were traditional conference style presentations of thirty minutes each, with two per month, which were held for one year.

We then received a suggestion from the chair of the microEP Industrial Advisory Committee (IAC) that these presentations be changed to a management overview format commonly used in high-tech industry. These presentations focus on current major events (both successes and problems), are limited to ten minutes, allow only two or three slides, and typically contain dense information on each slide.

Introducing this "management review" style format was very uncomfortable to the students, but it has trained them now to focus on key items. It has more importantly given them a real-life perspective on how management decisions are quickly made in industry. The unintended benefit of this program is that the students are now taking these intense presentations of their key research findings on interview trips, and these presentations have been mentioned by the hiring managers as having a significant positive impact on the internal hiring decision process.

The most controversial management training that has been implemented in the microEP Graduate Program is the use of formal research planning, with monthly reporting of detailed research plans using Microsoft Project software. Faculty acceptance of this student requirement has been only moderate, with the most common refrain being that "you cannot plan research". In fact you can plan the execution of research, which gives you more free time to unleash creativity (creativity being in fact an event that is impossible to plan).

Surveys of microEP alumni and members of the microEP IAC indicate that about half or the program's graduates routinely use Microsoft Project in their jobs, and about another quarter are in positions where it is available to be used. While the debate remains active on both the subject of research planning and the use of Microsoft Project, requiring both of all our students is bringing benefit in our graduates' research execution, job search, and early career success.

One valid critique of research planning starting with Cohort 4 came from the students when they noted that they were not receiving significant feedback from their monthly submissions. This was due to nothing more than the increased organizational size with no increase in management resources. The problem worsened for the next two years as microEP continued to grow, and it was only relieved when a new approach to giving our senior microEP students management practice was implemented.

Starting in the fall 2004 semester, students in the first two years of their graduate education were formed into small work groups of four to five students, with each of these groups led by a senior level microEP student. The group leaders were given the responsibility to (1) lead peer discussions of research progress and planning by the less experienced grad students, and to (2)

develop the new students' skills in the use of Microsoft Project such they would be proficient in the software tool's use at the end of two years.

This has been the single most successful method of giving our students practice in one of the most common management problems – being given more responsibility that your are given authority. It has given our group leaders the challenge of analyzing their own reasons for lower than optimal use of research planning while forcing them to become more proficient in their own use of the software.

The group leaders meet monthly with the microEP management team to discuss the problems they are facing in leading their groups, with very lively discussions between the group leaders on management techniques that have been effective and ineffective. These monthly meetings are typically at lunch time, with the program providing sandwiches for the working lunch meeting. This approach has resulted in multiple positive benefits in management training and practice that far exceed the costs to the programs.

An interesting outcome of this method, now in its fourth semester, has been the increasing frustration of the group leaders in some of their students' lack of planning of their research, and in some of them not meeting the obligations of the graduate program. A brainstorming session was held recently with the group leaders to find methods to address this, and a very interesting combination of carrot and stick emerged. The month meeting will now be used for four students to present their project plan to this student peer group of project group leaders, with the group leaders selecting one student from their group for the presentations.

The carrot comes from the best planning process displayed each month will win a $50 reward from the microEP program, with the right to compete at the end of the year at a program wide meeting for a $200 prize. The stick comes from the fact that each group leader can choose to bring before the peer group their worst performing student, who will then receive appropriate response from the group leaders on how to improve their planning process (and they may be invited by the group leaders to return the next month to verify that they have improved the research plan).

Summary

The microEP Graduate Program has experimented in many ways over its eight year existence on methods to embed management instruction and practice for our students into the normal operational environment of the program. This is still an experiment in progress, even though several of the techniques, policies, or procedures that have proven success are now part of the microEP culture at the University of Arkansas.

It is hoped that some of these techniques will be evaluated in other programs, and the microEP management team is available to work with other institutions' faculty members to identify and implement other methods to accomplish the goal of management training of our students.

Bibliography

1. Vickers, Salamo, Foster; “Microelectronics-Photonics Interdisciplinary Science/Engineering Graduate Program Startup – Lessons Learned at the Five Year Point”; ASEE Annual Conference; Portland, Oregon; June 04