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Research Seminars as a Resource in Mentoring Undergraduates

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This paper presents the results from a nine-year strategy of using research seminars as part of a program to aid underprivileged undergraduate students gain perspective and self-confidence in their professional fields. A national scholarship was awarded each semester based on merit and need to students preparing for careers in computer science, engineering and mathematics. One condition for continued scholarship awards was attendance at two technical seminars each semester given by visiting researchers from other institutions. Students were free to select seminars in any field from science and technology, in consultation with their faculty mentor, and were also required to submit a formatted summary of the technical content and their learning experience. This seminar requirement exposed many issues faced by undergraduate students, such as the importance of writing skills and time management. Overall, seminar attendance resulted in students finding interests far beyond those presented in their curricula. Over time, this experience proved to be a key feature in preparing the students for competitive technical fields. Alumni surveys and quantitative measures of student achievement support the validity of this technique. Effective practices to market technical seminars to a university population were also discovered through student feedback.

INTRODUCTION

At the close of the twentieth century, the United States (US) Congress allotted a portion of the fees charged for H-1B visas to the National Science Foundation (NSF) to address the shortage of qualified US professionals in these fields. From this allocation, the NSF created the CSEMS (Computer Science, Engineering and Mathematics Scholarships) program, competitively awarding scholarship grants to be administered by US universities. Typical grants provided $100,000 per year to be distributed free of overhead charges, with no more than $3125 granted to each student per year. Recipients had to be

US citizens or permanent residents, and they were required to qualify for financial aid under the FAFSA (Free Application for Federal Student Aid) criteria. The students' progress was tracked electronically where data on fields of study, academic progress, and post-graduation choices of career or higher studies were reported back to NSF and Congress.

The initial CSEMS grant at the Georgia Institute of Technology (GIT) was awarded in 2001 and was named the "Financial Aid for Success in Technology" (FAST) program. Some of the features of FAST, not necessarily unique, set the context of this paper. The diverse project team traced their origins to three continents and consisted of faculty who were active in research, teaching and mentoring at both graduate and undergraduate levels, as well as senior professionals from GIT's financial aid division. The team viewed FAST as a way to assist students reminiscent of themselves, with much more enthusiasm for learning than financial means to achieve their goals. They also viewed consistent and continuous mentoring by faculty members as a crucial asset in providing guidance that may not have been available from the student's family or secondary education. The financial aid personnel confirmed anecdotal experience: at a public institution, there is no shortage of students with moderate to severe financial need, whom they then helped prioritize for award of the scholarship. Since GIT faculty are intensely involved in sponsored research activities with numerous avenues for funding graduate studies, this scholarship was limited to undergraduates.

The FAST student cohort also had special characteristics. The NSF did not specify a preference for any particular demographic characteristic. The project team was free to select students based on academic credentials, CSEM career potential and financial need. A number of applicants came from homes with no prior familial tradition of CSEM professions or college attendance. Initial awards were made for one semester, with renewal contingent on satisfactory academic progress, continued enrollment in a CSEM major, and satisfactory completion of the requisite mentoring activities, which included attendance at two seminars and submission of two-page summaries describing these seminars. In nine years, over 200 students received FAST scholarships. The $800,000 was distributed primarily in $1000 scholarships each semester and resulted in approximately 800 individual awards. The overall progress of this project was reported in two ASEE papers [1,2].

Related Work

Zamorski *et al* [3] "set out to investigate the reality of the university rhetoric concerning the relationship of research to teaching" and studied what academics and undergraduates mean by research-led teaching. Kozeracki *et al* [4] report on a program centered about a rigorous seminar course used to mentor undergraduates for entry into the doctoral program. Students cited a competitive advantage stemming from the enhanced ability to read and present primary scientific research. Clark [5] traces traditional practices in German, British, Japanese, French and American universities. The British include an immersion experience that mentors an elite set of undergraduates for doctoral programs to create a "thin stream of excellence". In contrast, the American university system has evolved into separate graduate and undergraduate programs with widely differing emphases. Clark concludes "the much-voiced view that research and teaching are incompatible is short-sighted and regressive." Wood [6] reports on a conference consensus that independent research experience for every undergraduate may be neither feasible nor desirable, but that transforming lecture courses to more inquiry-based and interactive formats may be an effective way to improve undergraduate education. Sabatini [7] has presented the benefits of undergraduate research experiences. Bressette and Breton [8] report on a bold experiment of requiring submission of "journal-quality" papers to an in-house publication as an active-learning component of undergraduate research experiences. Russell *et al* [9] surveyed 15,000 undergraduates, showing that undergraduate research helped clarify and encourage students' interests towards higher education. The authors' personal experience [10] shows over 150 undergraduates using their experience with research teams as a springboard to internships, scholarships and careers, where a large majority of the group gained some level of graduate education.

There was a restriction on the CSEMS programs by the NSF Education and Human Resources Division that program recipients were not to be required to participate in research, as that would defeat the purpose of providing release time to concentrate on coursework. Thus a different strategy was needed, to bring in the experience of interacting with people who had to work and compete at the leading edge of endeavor in their chosen professional areas. Such an experience, according to the authors' experience, was the key to opening eyes and horizons, and was especially valuable to students coming from environments where such opportunities might not have existed.

RESEARCH STATEMENT

In a research university, there is a limitless wealth of opportunities for students to broaden their horizons, gain depth in desired areas, and gain access to the professional world. However, some undergraduates will complete their years in university largely insulated, unaware and/or disinterested in this aspect of learning. Certainly, numerous exceptions exist and have proliferated in recent years at GIT, with support for the synergy between undergraduate education and research. Students coming from higher socio-economic strata, particularly with parents pursuing technically oriented careers, are naturally aware of, and able to locate or network, learning and personal growth opportunities. However, their classmates from rural and less privileged backgrounds are often unaware of these opportunities and skills. One-on-one mentoring aimed to bridge this disparity by guiding students to the numerous opportunities beyond the classroom.

Given the above, the primary goal of the mentoring component of the CSEMS project coalesced into finding an effective approach to help undergraduates from lower economic backgrounds gain the perspective and skills needed to find and use opportunities outside the classroom for technical and professional development. The professional development milestones included helping students secure summer jobs or internships, enter the cooperative plan (students work in industry or government labs during alternate semesters), and win other scholarships. Achieving these goals requires some level of perspective, initiative, writing skills and professional communication beyond what is learned in the traditional classroom. An effective mechanism to foster such skills, without demanding many hours of individual mentoring from faculty, was required.

Hypothesis

The prolific number of technical presentations made by engineers and scientists from industry, other academic institutions and government laboratories every year at any university, was identified as a resource that could be exploited to provide mentoring and professional development, while also improving technical communication skills. Attending research seminars is rarely a high priority on an undergraduate's short-term academic calendar. Most undergraduates presume such seminars to be too obscure and incomprehensible. However, it was hypothesized that these technical seminars could be used to augment classroom technical material, spark interest in new areas of research, and provide incentives to help maintain interest in students' chosen majors. In addition, it was postulated that having to prepare a technical summary would improve writing skills and establish an ability to capture the essence of a deeply technical presentation by careful listening and thinking. Interaction with the speaker and familiarity with his or her research could also result in a competitive advantage when interviewing for jobs or graduate school. Finally, it was hypothesized that student would gain self-confidence, which would allow them to gain the confidence to embark on cross-disciplinary and innovative projects. The most risky postulate of all was that undergraduates could be induced to sit through research seminars, and learn to come away grasping, and able to articulate, the essence of the seminar. This, with all due respect, was a risky postulate even if it were about graduate students or most young engineers in industry.

Scope and Objectives

In this paper the focus is on the seminar component of the CSEMS program at GIT. The primary objective is to extract and present the significance of the seminar attendance/summary experience on the students. First, the model for student mentoring is described, where research seminars play an important role in the undergraduate experience. This is followed by a discussion of the performance of this model. The means to improve and transfer the model to other programs are explored.

THE RESEARCH SEMINAR REQUIREMENT

The FAST students were distributed over the various CSEMS disciplines, spanning eleven disciplines in the College of Engineering, two in the College of Computing, and three in the College of Sciences. An initial prototype proposed invited seminars by alumni and others tailored to inspire students towards technical careers. However, the diversity of disciplines, levels and class schedules made it impossible to find common times. After some iteration, the requirement was defined so that students chose technical seminars from the frequent offerings across the university schools based on their own interests and majors, in consultation with their FAST faculty mentor. The choices had to be approved by their mentors to be counted towards the requirement. Research seminars, as opposed to recruiting presentations were required. A further condition mandated that the seminars had to be given by speakers from outside GIT. Visiting presenters provide different approaches from what the home faculty (the teachers of the students) might convey. Further, interaction with visitors would help students to develop interpersonal skills and perhaps begin networking for employment.

Students were asked to submit a one to two page summary of each seminar that they attended. A format was specified to ingrain the skill of following guidelines in professional writing (e.g., proposals, project reports, archival research papers) that are critical throughout their careers. The 800 semester awards resulted in approximately 1600 unique seminar summaries that were read and approved by the project team (primarily the student's mentor and one of the project team). It was not unusual for neophyte recipients to iterate one or more times on their initial submission to satisfy correct

Seminar Author and Title
• Bettadpur, S., "Satellite Determination of Earth Gravity Field: The Past, the GRACE Mission and the Future". • Bleloch, G., "Parallel Thinking". • Boyd, Iain D., "Particle and Continuum Computation of Nonequilibrium Hypersonic Aerothermodynamics" • Burns, M.A., "Control of Micro Fluid Devices" • Cashdan, J.S. "K&S Antitrust Basics" • Deo, S., "The Impact of Size and Occupancy of Hospital on the Extent of Ambulance Diversion: Theory and Evidence" • DeSmidt, H., "Active Structural Damage-Identification of Time-Varying Rotordynamic Systems" • Dixon, S., "Doubles, Cyborgs and Multi-Identities in Digital Performance and Cyberculture" • Drela, M., "Transport Aircraft Optimization" • Finzi, L., "Elucidation of the Mechanism of the bacteriophage epigenetic switch" • Flaherty, K., "Benefits of Air breathing Hypersonic Propulsion for Flexible Access to Space" • Forrest, S., "Electronics on Plastic: Solution to the Energy Challenge, or Just a Pipe Dream?" • Johnsen, E., "Toward Numerical Simulations of Compressible Multiphase Flows" • Kim, P., "Graphic Carbon Nanostructures: From Analogy of Relativistic Quantum Mechanics to Carbon Based Electronics" • Kippelen, B., "Organic Photovoltaics: Status and Promise" • Law, C-K., "Advancing Combustion Science through Aerospace Applications" • Livshits, G., "Bioinformatics and Computational Genomics" • Lynch, W., "Biochemical and Environmental Applications of Nanotechnology" • McGaughey, A., "Phonon Transport in Semiconductor Superlattices" • McKinney, R., "Aircraft Turbine Combustors – Fundamentals of Design and Operation" • Nadler, J., "Porous Copper Composites for Microelectronics Coding". • Ozdoganlar, B., "Multiscale Manufacturing and Dynamics Lab: An Overview" • Sammakia, B., "An overview of the Research at the Small Scale System Integration and Packaging (S3IP) - A New York Center of Excellence" • Sato, M., "Millimeter-wave IC developed in Fujitsu Laboratories" • Scolese, "The Grand Challenges of Engineering" • Shalan, M., and Shin, E., "DX-Gt: Memory Management and Crossbar Switch Generator for Multiprocessor System-on-a-Chip." • Stickney, J., "Nano@Tech Electrochemical Atomic Layer Deposition" • Swartout, M., "Proximity Operations and Docking of a 3-kg Spacecraft: The Interplay between Design, Sensing and Control" • Volakis, J.L., "Antennas and RF Sensors: Changing the Way We Live". • Whitesides, G.M., "Biomedicine and Materials Science". • Wygnanski, I., "The Control of Separation and Circulation". • Yakimeno, O., "The Direct Method of Calculus of Variations as a Foundation for Rapid Prototyping of GN&C Algorithms for Aerospace Vehicles" • Yang, C-C., "Indium Aggregated Quantum Dot Structures and Their Optical Properties in InGaN Compounds." • Molinari, "A Multiscale Modeling of Dynamic Damage by Micro-voiding" • White, A., "Lifecycle Simulation" • Calabrese, R., "Modeling a Neuronal Network at Three Different Levels: Lessons from the Leech Heartbeat Central Pattern Generator. • Wadler, P., "As natural as 1-2-3" • Edwards, E., "Environmental Applications of DNA Microarrays"

TABLE 1

SAMPLES OF THE SEMINARS REPORTED BY THE UNDERGRADUATES IN THE FAST PROGRAM.

formatting, spelling, and grammar in addition to meeting the technical objectives of summary. It was rare (~2%) that students did not learn from their initial efforts.

RESULTS AND DISCUSSION

Cross-Disciplinary Seminar Selections

The seminar topics chosen by the students were very diverse, far beyond what a set syllabus of presentations would have entailed. In retrospect, this diversity was not surprising given the wealth of such resources on a research university campus. A small sample of seminars used to satisfy this requirement is listed in Table 1. While many seminars were well advertised across the campus, so that several students attended the same seminars, there were also numerous interesting exceptions. Some students sought out seminars far outside their majors. Since there was no grade attached to the requirement, they were thus able to learn well beyond their academic majors. This willingness to explore, and the demonstrable gains in depth and perspective by some participants are probably the most exciting findings from this experiment.

Student Perspective

A portion of the seminar summary included a personal evaluation of the student's response to the seminar. These responses indicated that seminar selections ranged from material that was too advanced to excitement that a confusing concept in class was explained to decisions on career paths. Four excerpts below show the short-term and longer-term evolution of students' responses and ability to gain from the seminars.

Student 1, first freshman seminar: *"This seminar was way over my head due to my being a first year student and the complexity of the topic. I learned that GaN-based are key materials for the development of light-emitting devices, high-power electronics, and solar blind UV detectors.* [The speaker] *then discussed the stuff that was way over my head. These topics included: the origin of self-organized quantum dot structures in III-Nitrides; spinodal decomposition; strain-induced piezoelectric fields; spontaneous polarization; InGaN quantum dot structures; the effects of post-growth thermal annealing; and the effects of silicon doping.* [The speaker's] *research seems to have very important implementations and many drawbacks that he must consider."*

Student 1, second freshman seminar: *"Once again, most of the material that was covered was over my head. Something that I did understand was that were trying to implement a processor that used multiple processing elements to do a task in parallel.* [The speaker] *then discussed the target architecture, the dx-gt, synthesis results, and SOC floor plan. Overall, the presentation was pretty interesting."*

Student 2, as a freshman: *"This seminar was fascinating, as I always wanted to know more about SpaceShipOne, and from a first hand source, too! The only thing I did not like about the seminar is that I think it was geared more towards the more advanced AE* [Aerospace Engineering] *majors, with respect to terminology and speed with which he went through the material. But all in all, it was a great seminar and I was glad that I attended it."*

Student 2, as a senior: "This was an amazing seminar and I am so happy I was lucky enough to attend it. [The speaker] *is a wonderful speaker and left the audience hanging on his every word as he relayed his experiences* […]. *It was educational throughout the* *lecture to hear the terms stated in classes used in real life scenarios. It brought the definitions 'to life' so to speak. Most importantly, I left the lecture with a renewed passion and pride for my field."*

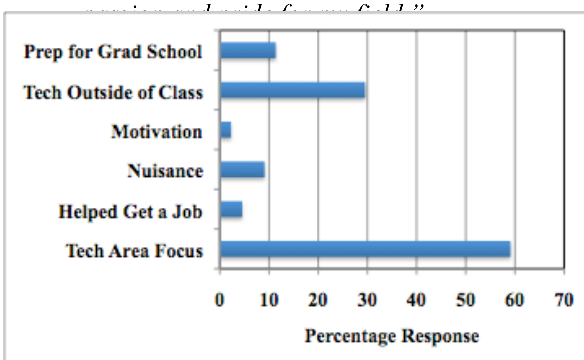

Figure 1: Student response to seminar requirements

...ards PhD level seminars are real, but the ...periences. Students' growth in technical ...ary comprehension are clear from their ...minars maintained their passion for their ... Student 2, for example, joined graduate ...e and seminal influence transparent.

...f the research seminar in introducing new *...nar was interesting in that it pointed out ...alized that the depth of possible areas of ...n,* [the speaker] *also presented some brief background information and knowledge required to understand the scope of his research so that it was easier to become engaged in the presentation."*

Forty-four responses from graduates (others are still approaching graduation) illustrate their views of the seminar requirement. They were asked how the seminar requirement had impacted their technical and professional development (Figure 1), and they were also permitted free form responses. Over half indicated that seminar attendance helped to narrow the technical area that they wished to pursue in graduate school or careers. Thirty percent learned more about their major than was provided in class, which included interesting and current research beyond the traditional curriculum. Thirty-six percent of the students indicated that they were attending graduate school, which indicates that many were able to apply the research seminars directly to their graduate school applications. Of the 57% of students who were directly entering the job market, less than 10% were able to parlay the research seminars directly into a job offer.

Free-form responses generally focused on the concepts of new technical material and how to perform research. Some typical responses include

- *"Improved my understanding of how science and technology advance. Gave me a better perspective of how my skills could be applied towards further advances."*
- *"Made me more knowledgeable about current research in my field."*
- *"Provided motivation to learn more about topics I'm interested in."*
- *"Gave valuable insight into what engineers do in the real world."*
- *"Helped learn more about my field."*
- *"I couldn't have successfully applied to graduate fellowships if it weren't for the seminars."*

Of the 9% of the students (4 students) who designated the seminars a nuisance, three had the common characteristics of going directly to a post-Baccalaureate job, and their overall grades fell below the mean graduating grade point average of the program participants. The other student indicated that the seminars were “Informative, but the write-up was a hassle.” The writing component of the seminar requirement was not evaluated in the exit survey, so it is difficult to extrapolate the cause and effect of writing on the overall student perspective.

Mentor Perspectives: Essential and Successful

Mentor perspectives provide key insight into the student reaction to the seminar requirements. Students who took the initiative early to explore for seminars sent in summaries that reflected genuine excitement and interest, as well as considerable introspection on how they fared in comprehending the seminars. The discipline of having to find and attend two seminars was a tough challenge to several students, in particular freshmen or first-semester transfer students. Most of these students responded to reminders. Those who did not were put on “probation” in the scholarship program for one semester and asked to attend a time management seminar offered by GIT. Over 80% of these students were able to successfully continue in the FAST program and completed their academic studies at GT. There is not a clear correlation in academic success and good time management practices with the seminar requirement, beyond the anecdotal. Mentors noted that students found it easier to find seminars as they completed more courses, and the most active attended many more seminars than were required.

Time management remained the overarching concern in meeting the seminar requirement. Procrastination led to frantic end-of-semester hunts for seminars. To avoid this, the effective solution was a requirement that the first seminar had to be attended and the summary delivered before the semester midpoint. Another modification based on mentor experience was to permit the substitution of a career placement seminar on interviewing techniques, resume writing, or cooperative education opportunities for one technical seminar. Graduating seniors were also encouraged to use the seminar substitution for career placement assistance. This modification was constructive in encouraging early professional development by the participants.

Seminar Advertising

One issue was that each school or department markets their seminars in different ways. Few have lower-division undergraduates in mind. Methods range from traditional announcements posted on a (physical) bulletin board or door, to school web calendars, to mass emails. Anecdotal evidence indicates that the most effective marketing appears to be a combination of posting seminar announcements in an electronic calendar on the school web site along with flyers posted at building entrances. Students from schools that employed only the traditional method of flyers posted in buildings had the most difficult time locating relevant seminars in a timely fashion. Students indicated that the volume of mass emails from their schools also made it difficult to locate seminars, as their first reaction was to delete these. A key need is to reach students who are not taking courses within the main school building. An electronic site to post important time-critical information, combined with effectively communicating the existence of this site is vital.

SUMMARY AND CONCLUSIONS

Integrating research seminar requirements into an undergraduate educational experience is merited based on the anecdotal and quantitative analysis presented. Specifically:

1. Research seminars can play a major role in identifying and focusing career choices.
2. Carefully selected seminars can augment curricula by providing current research topics, techniques and future paths that cannot be addressed during class lectures.
3. Research seminars have not been shown to be a major source of direct hiring contacts, but provide secondary benefits in broadening career choices and preparing for graduate school through the introduction of research areas not covered in undergraduate courses. They also serve to identify universities and faculty whose work interests particular students.
4. The largest obstacle to using research seminars as part of the undergraduate experience is appropriate time management, in particular for the lower level (freshman-sophomore) cohort. Integration of research seminar attendance into a scholarship program, as was done here, or as a graduation requirement, rewards student attendance.
5. Lack of appropriate seminar advertisement is a major issue with undergraduate student attendance. Electronic notification is necessary given the target audience who are most comfortable with this medium. Failure to regulate the number of electronic messages can have an adverse effect. Multiple marketing strategies are warranted, as is ensuring that all students are aware of where to find this information.
6. An unexpected aspect of the experiment was the breadth of seminars far outside their traditional major chosen by students. This has very interesting implications to learning and innovating across disciplines that should be further explored and exploited.

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