AC 2008-553: SCHOLARSHIP RECONSIDERED AND ITS IMPACT ON ENGINEERING AND TECHNOLOGY GRADUATE EDUCATION

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Scholarship Reconsidered and Its Impact on Engineering and Technology Graduate Education

Abstract:

Boyer's model of scholarship classifies scholarships into discovery, integration, application, and teaching. Since its inception in 1990, this model has impacted university faculty's perception of scholarship as well as Tenure, Promotion, and Reappointment (TPR) policies of many universities.

This paper discusses the impact of Boyer's model on engineering and technology graduate education. The "GREAT" model, standing for Graduate Research, Engagement, Applications, and Teaching, is proposed. Implementation processes and results of this model in the Master of Science in Technology (MST) program at Western Carolina University are reported, and implications of further research on the impact of engineering and technology graduate education are discussed.

Introduction

In his book "Scholarship Reconsidered," Boyer argued that scholarships should be expanded beyond pure research. He classified scholarships into four categories: discovery, integration, application, and teaching [1]. This is the well-known "Boyer's model of scholarship." Since its inception in 1990, Boyer's model has been widely discussed and debated, and the focus has mainly been on its impact on university faculty, especially their tenure, promotion, and reappointment (TPR) policies [2, 3].

However, scholarships are not generated by faculty alone. Our students, especially graduate students, are an important integral part of the scholarship. They serve as a backbone of pure research (discovery), a vehicle of implementations (integration and application), and a bridge between faculty and the students, graduate and undergraduates alike (teaching). Their efforts of generating and improving the quality of scholarships can never be undermined, and adoption of Boyer's model definitely sets a new direction of graduate education in terms of scholarships.

This paper introduces a new model for graduate education under Boyer's model of scholarship, "GREAT," stands for "Graduate Research, Engagement, Application, and Teaching." The paper discusses the impact and expands the implications of Boyer's model on engineering and technology graduate education by exploring the meanings of fundamental research, industrial engagement, real world applications, and enhanced teaching activities. During the past three years, the "GREAT" model has been implemented in the Master of Science in Technology (MST) program at Western Carolina University. This paper reports the implementation processes and results.

Implementation I – Student Selection

The MST program was originally developed to help working professionals in the region to further their technical knowledge in technology-intensive systems and their managerial skill for career advancements. Due to rapid growth in recent years, the direction of this program has changed to cover applied engineering research and applications. Both thesis and non-thesis options are available. Students came with a variety of technical backgrounds. Therefore, student selection is vital to the implementation of the GREAT model. Currently, the program enrolls about 30 students. Table 1 summarizes the distribution of the students in terms of their backgrounds, thesis options, work experiences, and resident status.

Table 1 MST Students Distribution (in %)

Academic Background		Work Experience		Thesis Options		Resident Status	
Electrical	Mechanical	Yes	No	Thesis	Non-Thesis	On-campus	Off-Campus
44	56	40	60	40	60	60	40

As can be observed from the above table, the program consists of a mixed student body. Off-campus students are working professionals with experiences span over engineering design, quality and process control, and community college instructions. These students chose non-thesis option which requires 30 credit hours to complete the degree. Most of the on-campus students do not have work experience, most enrolled into the program after completing their baccalaureate degrees. About 67% of these students chose thesis option, and all of the on-campus students hold Teaching Assistant (TA) or Research Assistant (RA) responsibilities. Some of them hold 50% TAship and 50% RAship. Thesis option students have their major advisors, while non-thesis students are advised by the graduate program director.

This mixed student body creates a favorable environment for implementing the GREAT model. The thesis-option students help their major professors conduct applied research projects (Discovery), the on-campus students engage with the industry by working on real-world projects brought by off-campus students (Integration and Application), and the TAs help professors with their innovative teaching projects (Teaching). Some example projects will be discussed more in detail in the following sections.

Implementation II – Curriculum Design

Like the students selected for the program, the MST program curriculum is also designed to improve the students' skills to engage research, industrial integration and applications, and innovative teaching methods development. The MST curriculum at Western Carolina University is shown in Table 2.

Table 2 A Typical MST Course Checklist

Area	Credit Hours	Course Number and Title
Core Area	3	ET 570 – Telecommunications Systems
	3	ET 603 – Research Methods and DOE
	3	ET 641 – Quality Assurance
	3	ET 642 – Automation Systems*
Support Area	3	ENGL 501 – Professional Writing
	3	A business or science course**
	3	A business or science course**
Directed Project	3, R6***	ET 688 – Directed Applied Research Project
Electives	3	ET 644 – Data Acquisition, Control Systems*
	3	ET 575 – Project Management
Thesis	3, R6***	ET 699 – Thesis Research

* One can be chosen as core, the other can be used as one of the electives.
** Non-thesis students normally take business courses in management, economics, or finance. Thesis option students normally take math or other related science courses.
*** Normally offered at 3 credit hours per semester, repeatable up to 6 credit hours.

It can be observed that this curriculum is well balanced to train the students' various sets of skills suitable for their career development. Our core courses provide the students competitiveness in research and applications. For example, ET 642 focuses on data acquisition skills using LabView software package, ET 570 centered at how to move data around using communication systems and networks, and ET 644 teaches various methods of data collection and how the data is arranged in a database. When data collection, transportation, and organization cycle is completed, ET 603 aims at the students skills of designing experiments and analyzing data using statistical tools. With the analysis results, ET 641 teaches the students how to interpret the results and apply the results in quality control and quality assurance. These basic skill sets enable our students to conduct applied research, integrate and apply their knowledge in real-world situations. It is worth mentioning that all these core courses involve semester-long projects that span over research, engagement, and innovative teaching.

ET 688 is probably the most crucial course in the curriculum. It serves different purposes for our students depending on their thesis options. Typically, non-thesis students use this course to demonstrate their abilities to conduct an applied research project by solving a real-world technical problem. For thesis-option students, they use this course as a vehicle to lead to their thesis research topic or proposal. The course is led and managed by one professor, but the projects are carried out by students working with different professors depending on their research interests. The projects can typically be divided into four categories that are in line with our mission: research, engagement, applications, and teaching. Research projects refer to those longer-term projects advised by individual professors or teams. These projects are more theoretical and aimed at possible research funding and grants. Engagement projects are mostly brought in by off-campus students. These projects are typically aimed at solving a specific technical problem in a company or an institution. Application projects are typically exploration of the capabilities of the state-of-the-art equipment and their potential application in real-world situations. Teaching projects are typically design and implementation of innovative teaching methods helping further the students' (mostly undergraduates) knowledge in specific courses. Example projects and results will be presented in the next section.

It is worth mentioning that for some projects that are valuable and whose scope becomes larger than originally expected, we encourage the students repeat ET 688 for another 3 credit hours to complete the projects. These extra 3 hours are typically used to substitute an elective course.

The support area includes 9 credit hours to further expand the students' knowledge that helps their career advancements. The professional writing class is required for all students to improve their communications skills. Business courses are taken by non-thesis students who are working professionals or will join the work force after graduation. The business courses improve the students' skills in understanding the organizations, management, economics, and business negotiations. For thesis-option students, we require our students to strengthen their technical research capabilities by taking math courses or science courses directly related to their research topics. The thesis-option students are also required to take extra 6 credit hours to complete their thesis. All students are required to take an oral exam to demonstrate their comprehensive knowledge or to defend their thesis.

Example Projects and Results

In this section, some example projects and results are presented to demonstrate the effectiveness of our implementation of the GREAT model. The examples are given under four categories: Research, Engagement, Applications, and Teaching.

Graduate Research

The example project presented is the "Detection and Analysis of Human Hand Tremors." This is a continuing research project aimed at detecting, analyzing, and suppressing human hand tremors. Results obtained thus far are outcomes of ET 688 and ET 699.

Phase I of the project was carried out by a thesis-option graduate research assistant. The main tasks involved in phase I consist of both hardware and software development. The hardware was a test-bed that simulates tremor motion to provide data for analysis. The hardware consisted of the Analog Devices ADXL330 3-axis accelerometer, combined with the EVAL-ADXL330Z evaluation board for data collection. Data acquisition was accomplished using the National Instruments (NI) USB-6008 DAQ and NI LabView. The tremor motion was simulated using a circuit designed to output 3 different frequencies to a vibration motor, resulting in motion in the range of human tremors. This project used two different data analysis methods: Empirical Mode Decomposition (EMD) and Auto-Regressive (AR) process of order p. Preliminary results show that each of these methods performed in a satisfactory manner.

From educational perspective, this project has provided invaluable graduate research experience. The skills and self-efficacy gained from this project have stimulated the graduate student's research interests and his desire of pursuing higher education at the doctorate level. Detailed research results and educational merits are reported in [4].

Graduate Engagement

There are three projects reported under this category. Two projects were conducted by working professionals (off-campus students) solving real-world problems for their respective companies. The third project has been carried out by an on-campus student with his advisor, engaging with a local industry. The first two projects were completed and the third one has achieved significant progress at the time of the report.

The first project was the development of a wireless monitoring system to improve process efficiency. The successful implementation of this system has greatly helped the managers break the physical ties from their machines and computer monitors. The wireless monitoring system has relieved some of the issues and therefore helped improve process efficiency at Blue Ridge Paper Products' extrusion coating facility located in Waynesville, North Carolina.

The wireless monitor device has had several unforeseen uses other than to allow managers to view efficiency of their process. The tool has allowed engineers at the Blue Ridge Paper's extrusion coating facility to more efficiently correct machine downtimes. This tool has also aided in engineering support for preventative maintenance. Process improvements measured by Key Performance Indicators (KPIs) as a result of this project is reported in [5].

The second project was the re-design of a brushless DC motor testing work station at the Moog Components Group in Murphy, North Carolina. It is a device that is used at final test on brushless DC motors that have the rotor magnet on the outside of the stator. A direct benefit of this engagement project was the increase of productivity. The project was carried out by the graduate student as his directed project (ET 688), and the student problem solving, project management, and other related skills gained through this graduate engagement project [6].

The third project consists of two sub projects: development of a microclimate system and design of a water quality monitor. The project is a collaborative effort of the graduate student, his advisor, and the Watershed Association of the Tuckaseegee River (WATR) in Bryson City, North Carolina. The student used these projects for the telecommunications systems course (ET 570). The microclimate system is a system for use on the land and incorporates sensors that detect temperature, light, soil moisture, and soil temperature. The water quality monitor has the capabilities to sense temperature, pressure, turbidity, and conductivity. The projects successfully demonstrated the graduate student's technical abilities, as well as the impact of these projects on graduate learning experience. A variety of real-world skills including infrastructure design, programming, protocol selection, data acquisition and analysis, and project management have been greatly improved through these engagement projects [7].

Graduate Applications

The example project presented here is a comparison of Comparison of Engraving Capabilities between the Haas CO_2 Laser and the Oxford Lasers Solid State Diode Pumped Laser. The Haas and Oxford are laser machining equipment acquired by the department for teaching and engagement purposes. The graduate student utilized his knowledge gained from ET 603 and designed an experiment to statistically analyze and compare the performances of these equipment. There are no current machining parameters or settings that will allow the user to accurately produce an engraved design with a quality finish. The machining parameters that are in question for both machines include; power (measured in Watts), frequency (measured in Hertz), feed rate (measured in inches per minute (IMP) and millimeters per second mm/s), and focal length (measured in inches and millimeters). This research includes all these parameters in a Design of Experiments (DOE) in order to statistically find the optimum settings for engraving. The experiment aims at determining optimum engraving parameters for 20 gage stainless steel at 0.034" thickness and to statistically compare the performance between the two machines. The same material will be engraved on both machines. The statistical and quantitative data gathered during the experiment provide both future researchers and users a guideline for engraving of not just stainless steel but other materials such as plastics and ceramics.

From educational perspective, this project has provided invaluable graduate research experience. Applications of knowledge gained from classroom to real-world practices well prepare the students for further career development. Technical results and educational merits are further discussed in [8].

Graduate Teaching

The example project reported in this category involves innovative teaching method development of designing a Direct Sequence Spread Spectrum (DSSS) system for undergraduate wireless communication labs. In most universities, DSSS labs are not available due to the expanse of such a system and level of difficulty of developing one. Although this technology can be demonstrated through the simulation using MATLAB, SystemView, or other software, however, it will be better to provide students first-hand learning experiences through hardware experiments. This system includes the hardware implementation based on Altera FPGA/CPLD development board and Mini-Circuit RF modules. Software simulation model will also be built based on MATLAB to verify hardware performances. Through the project, the graduate student acquired an in-depth understanding from a systematic perspective and well-trained professional skills useful for further study and research. On the other hand, the outcome of this project-the DSSS system was directly designed to enrich the undergraduate wireless communications laboratory experiments, and it helps undergraduate students obtain better theoretical understanding as well as hand-on experiences of spread spectrum technology and CDMA system. This integration teaching method improves the teaching quality by combining the graduate education with undergraduate education in an appropriate way, which is also meaningful for other disciplines [9].

Conclusions and Future Work

This paper reported the implementation and impact of the GREAT model, which is a model for graduate education through research, engagement, application, and teaching. This educational model is greatly influenced and inspired by the Boyer's model of scholarship that includes discovery, integration, application, and teaching. The examples shown in this paper report promising results that the GREAT model can significantly impact and benefit the graduate students' learning experience. They also demonstrate the benefits of industries can gain from these projects. Further assessment tools need to be developed to assess quality improvement both qualitatively and quantitatively.

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