Engaging Engineering Graduate Students in Applied Research at Morgan State University

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Abstract

Graduate study provides a passion and a pathway for students to pursue advanced education or career advancement. Many Morgan State University (MSU) graduate students come from economically disadvantaged families and have very limited financial support for their full-time graduate study. Some of them solely count on the scholarships provided by the school or have to take out student loans. Supported by National Science Foundation (NSF) Scholarships for Science, Technology, Engineering, and Mathematics (S-STEM), NASA research grants and other Federal research grants, many MSU engineering graduate students have been involved in applied research projects with NASA Goddard Space Flight Center, Army Research Laboratory, and the local industry. These projects include but are not limited to the reliability and maintainability study for McMurdo antenna system, integration of the NASA systems engineering approach into software defined radio technology development projects, etc. Through the involvement in applied research projects, these MSU graduate students benefit significantly in terms of inspiring their research interests, developing skills to collaborate with engineers and scientists of Federal laboratories or industry, and enhancing their future employability. In this paper, we will discuss several graduate student outcomes and statistical analysis for the impact of the applied research topics and NSF S-STEM scholarships on the student's performance in graduate study and career development. Our experiences have convinced us of the effectiveness of this setting, which can not only retain students' vigorous interests and enthusiasm, but also enhance their employability in today's job market.

1. Introduction

Participation opportunities in funded research projects are an important factor in attracting talented graduate students. Science, Technology, Engineering and Mathematics (STEM) fields play an important role as an economic engine for today's economic development. Indeed, the competitiveness in STEM fields is basically considered as a benchmark for the country's global competitiveness. In the United States, the Federal Government has set up various policies and set aside funds to support the STEM workforce development to maintain American economic competitiveness and leading roles. The workforce development in engineering is even more important in dealing with the significant global competition from other fast-growing economies.

As a historically black college/university (HBCU), Morgan State University (MSU) is an advocate of diverse STEM workforce pipeline development. MSU is classified as a doctoral/research university (DRU) under the Carnegie classification system. Under the

leadership of MSU President David Wilson, the University has developed a ten-year strategic plan [1] that includes a vision to propel the University from the current DRU Carnegie classification to RU/H Research University (high research activity). The MSU School of Engineering offers the Doctor of Engineering (D.E.N.) and Master of Engineering (M.E.N.) degrees, which focus on applied and interdisciplinary research topics for graduate dissertations and theses, rather than pure and theoretical research topics. The School of Engineering also offers Master of Science degrees in Electrical Engineering, Transportation and Urban Infrastructure & System studies.

Graduate study provides a passion and a pathway for students to pursue advanced education or career advancement. Many MSU graduate students come from economically disadvantageous families and have very limited financial support for their full-time graduate study. Some of them solely count on the scholarships provided by the school or have to take student loans. Supported by NSF S-STEM scholarships, NASA research grants and other Federal research grants, many MSU engineering graduate students have been involved in applied research projects with NASA Goddard Space Flight Center, Army Research Lab, and the local industry. To name a few, these projects include the reliability and maintainability study for McMurdo antenna system, and integration of NASA systems engineering approach into software defined radio technology development projects, *etc*. By being involved in applied research projects, these MSU graduate students benefit significantly in terms of inspiring their research interests, developing skills to collaborate with engineers and scientists of Federal laboratories or industry, and enhancing their future employability. In this paper, we will discuss several graduate student outcomes and statistical analysis for the impact of the applied research topics and NSF S-STEM scholarships on the student's performance in graduate study and career development. Our experiences have convinced us of the effectiveness of this setting, which can not only retain student's vigorous interests and enthusiasm, but also enhance their employability in today's job market.

The graduate curricula in the Clarence M. Mitchell, Jr. School of Engineering at MSU have a focus on encouraging graduate students to conduct an applied research project with industry or Federal laboratories, government agencies or research centers. Specifically, Master's degree candidates need to complete an applied research project of four semester-credit hours in a period of 1 to 1.5 years, while doctoral candidates need to complete a dissertation focusing on applied research in a period of 1.5 to 3 years. A total of minimal 33 semester credits are required for the Master's graduate student (one semester credit is equivalent to about 15 hours of course lecture time in a semester), while usually the Master's graduate student must complete more than 10 semester credits of coursework before he/she should start the research project which consists of Research Project I (2 credits) and Research Project II (2 credits). Similar to the setting for doctoral dissertation, most master-level graduate students are required to make a professional presentation on the research proposal in Research Project I. After the proposal is approved, the student will spend one more semester or even more than one year to conduct the research, and

then the student will be required to make a professional presentation on his or her completed research project to summarize the research findings. These presentations are open to public and the students are interrogated by challenging questions from faculty, industrial sponsors and colleague students. Through this process, the graduate students can significantly enhance their hands-on capabilities and applied research-oriented critical thinking. Their communication skills through presentations can also be significantly improved. In the following sections, we will share our experiences in conducting applied research projects with graduate students in civil engineering, electrical and computer engineering, industrial and systems engineering, and transportation studies by several case studies. Consequently, we also perform assessment analysis to generate the evidences of the benefits to the students and effectiveness of this module of engineering education setting.

2. Graduate Applied Research in Civil Engineering

In the department of civil engineering, a doctoral student is investigating the problem of aging underground utilities, which is now a typical problem with road transportation systems. This has become a significant source of environmental pollution and traffic congestion in the City of Baltimore. Underground Utilities in the City of Baltimore, like other cities in the United States, include a large number of utilities that can be described as old infrastructure that is nearly worn out due to the stress over its time in service. These roads are the main conduit for the distribution or movement of energy. Water, sewers, waste, telecommunications and storm water, are along with a complex lattice of pipes, cables, and wires. On the roads, the utility managements are digging hundreds of thousands of holes as they renew or repair old networks, and there are also several billions of dollars of new investment in underground infrastructures. The City of Baltimore had built good underground utilities and roads, and offered its citizens quality life. For decades, these infrastructure developments worked so well that they were taken for granted. Today, however, years of neglected repairs, a broken funding system has left the City's underground infrastructure in desperate need of an overhaul. The impact of aging underground utilities is on an increasing trend with leaking steam through cracks and manholes, and other visible influence on the streets of Baltimore. It is an extremely important issue in assessing the environmental safety of the City. Among the destructive effect of these aging utilities, is the traffic congestion caused by frequent process of repairing these aging utilities, fixing damages like sink holes caused by gradual disintegration of underlying soils. In the case of steam pipe leakage or damage, the release of stream into the environment cause reduction in driver’s view and as well reduce the service life of the pavements by buckling the Asphalt and reducing the maintenance interval.

Despite the fact that a lot of research has been formally carried out to discover and examine the practical relationship between air pollution/air quality, and the road transport as well as underground utility equipment. Additional enhancement in the significance of this correlation is

also important. It is the objective of this graduate study to research the correlation between aging underground utilities, road transportation and the speculated environmental impacts and also to establish a more resilient framework to bridge the link between road transport emissions from disturbed traffic flow as a result of aging utilities, and air quality concentrations. This study is being done in conjunction with the City of Baltimore Transportation division. .

Another graduate student is investigating chemicals of emerging concern (CEC). People are still unclear with the persistence, bioaccumulation potential, and the effect of CECs on human health, aquatic systems, and marine life. As these new compounds and chemicals are detected in potable and treated wastewater effluent, public health awareness and environmental concerns have grown. New technologies are developed in minimizing the risk and health hazards that these CECs may pose to humans as well as wildlife. However, some CECs still remain ubiquitous within the environment, and their ultimate fate poses an emerging need for treatment. The aim of this study is based on assessing the distribution of CECs. The persistence and sorption affinity of these CECs to sediment substrates, allow for complete transport throughout entire watersheds and beyond. This study discusses a series of methods used to quantify and map the spatial extent of these pollutants and possible drivers leading to their distribution. Descriptive analysis provides an insight on the association between land-use practices and possible point sources. Results can enhance our ability to understand and analyze the spatial and temporal patterns of CEC pollutant loading within riparian watersheds.

3. Graduate Applied Research in Electrical and Computer Engineering

In the Department of Electrical and Computer Engineering, students are engaged in projects that often have corporate or Federal sponsors and the projects are application-based. Thus, student work is heavily impacted by the availability of mentors and advisors with these ties. There is strong interest in language recognition within intelligence and other communities. A recent project involved developing a method to rank the performance of several Gaussian mixture models based on performance in a given data set [2]. Another student in the Department is working on implementing packet filtering techniques to increase security, using system-on-chip, with specific application in software-defined networking. This project is focused on a new network architecture that can accommodate the ubiquitous nature of cloud computing and mobile devices. A third graduate student project utilizes predictive analytics to maintain transformer equilibrium in the presence of electric vehicles. The work finds a solution for this challenge, which can, in real-time format, reduce the potential of power loss.

The Doctor of Engineering degree at Morgan State University allows students to conduct research in electrical engineering and on topics that span multiple disciplines. One example is a student project using engineering models to assess physical activity in high schools [3]. The research team is developing a performance assessment model that can be utilized by schools and

school districts to determine current strengths and areas for improvement. The model integrates the presence of structures in the established environment, which promote physical activity to the extent that they are utilized in the curricular and co-curricular activities. The model utilizes neural networks to develop a scorecard. Project partners include local schools and school districts. Another example is a student project that utilizes a neural-network-based system to predict student performance on high school grade point average, standardized score utilized for college admission, and student academic performance in the first year of college. The training samples are designed using a K-Nearest Neighbor rule instead of a large training set.

4. Graduate Applied Research in Industrial and Systems Engineering

Over the past few years, several graduate students have participated in the applied research projects, collaborated with NASA engineers at Goddard Space Flight Center (GSFC) in reliability and risk analysis division and systems engineering division. These students have been working on the real NASA research projects. This research collaboration also leads to several related academic papers [4-12]. Specifically, the graduate students have participated in the following applied research projects related to NASA's missions:

- Novel Uses of Multi-modal Design, Failure and On-Orbit Anomaly Data for Improving Reliability and Risk Analysis
- Radome Availability and Maintainability Study – to study the degradation of Radome panel materials under the extreme weather conditions, such as McMurdo station in Antarctic or Guam
- Reliability and maintainability study for McMurdo antenna system
- Integration of systems engineering approach into software defined radio technology development
- Categorizing the database of Spacecraft Orbital Anomaly Report System (SOARS)

The student's experience in working with NASA engineers or industry can significantly enhance their resumes for future employability. For instance, after conducting Master's research project on reliability with NASA engineer, an M.E.N. graduate received several job offers as reliability engineer from Zodiac Aerospace, BGE and a consulting firm. Another M.E.N. graduate, who conducted an applied research with NASA engineers at GSFC for his research project, received an offer from Lockheed Martin System Integration division, and his work at Lockheed Martin is closely related to his Master's level research project.

Categorizing the database of Spacecraft Orbital Anomaly Report System (SOARS) is a current project to help the reliability and risk analysis of future space mission. In this section, we will specifically discuss this on-going project.

In order to make the proper advances in safe, reliable and successful spaceflight and exploration, we must both learn from unexpected outcomes or failures, and properly understand consistent operational successes. SOARS database has recorded all operational anomalies of spacecraft and subsystems related to GSFC missions since 1972. SOARS provides a single uniform, effective, and efficient computer database for in-orbit reliability studies to identify performance trends for use in design reviews, flight readiness reviews, and in the evaluation of test, reliability, and quality assurance policies. To increase the safety of the future space missions, it is important to enhance the reliability and risk analysis. It can significantly help the accuracy and convenience of the future reliability and risk analysis if MSU students can collaborate with the engineers at GSFC in categorizing the anomaly data according to failure cause and mode, relating the anomaly data to the proximate cause of the failure for reliability analysis purposes. The failure mode and effects analysis (FMEA) and fault tree are important tools to be used to link the original causes to the anomaly operation events.

The goal of SOAR is to report anomaly operation immediately after the occurrence of an anomaly. The reporting procedure is given in the flowchart in Figure 1.

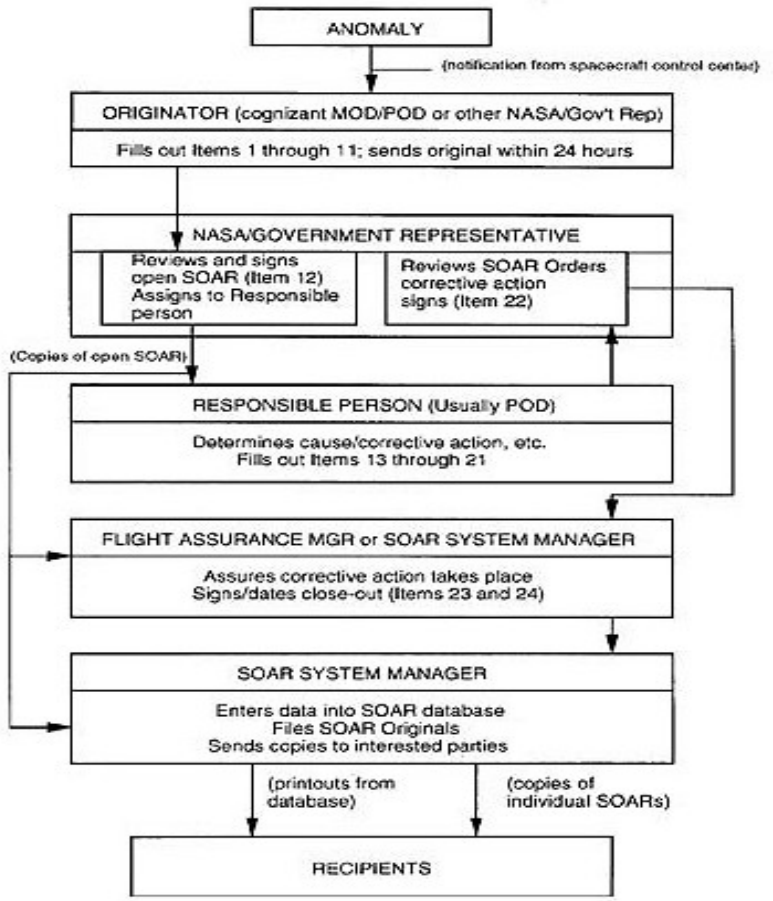

Figure 1. SOARS Flow Diagram

Although there is a variety of design, testing and on-orbit data available in SOARS database to the reliability group at GSFC during development, these data are given as schematic data, numerical data, and text data, which may contribute valuable lifetime and risk-related information. Categorizing these data for the purpose of probabilistic modeling for risk assessment is not a trivial task. MSU students will conduct this task, according to the failure cause and mode, relating the anomaly to the proximate cause of the failure for reliability analysis purposes. Experimental design and factorial design concept may be integrated to find the significant causes and the possible interactions between various factors. The MSU graduate students will perform the research with exposure to the real NASA project development environment. They also receive training on the use of SOARS database. Specifically, their technical tasks include:

- Organization of available data into vectors suitable for input into statistical modeling software (data segments will be provided by NASA Engineers and directly established for the students).
- Performance Benchmarking of competing statistical models and parameter estimation methods under direction of NASA engineer mentors.
- Suggestions for further investigation based on student experiences in working with the data
- Reporting and Analysis of Benchmark Results
- Suggestions for how project results can improve current, ongoing and forthcoming projects
- Assistance in preparing scholarly papers in referred journals, conferences or NASA Technical Memorandum incorporating all prior work, results, conclusions

5. Graduate Applied Research in Transportation Studies and Engineering

In the department of Transportation and Urban Infrastructure Studies, doctoral students are heavily involved in applied research. One student is participating in Highway Safety Manual related research. Currently, Highway Safety Manual suggested local calibration process. The research team has conducted the local calibration for the State of Maryland, and the doctoral student actively participated and suggested for the project. As a result, the research team including the doctoral student has presented three papers at 2015 Transportation Research Board Annual Meeting in Washington DC.

One student research paper discusses Maryland's experience in developing local calibration factors (LCFs) in the application of the Highway Safety Manual (HSM), the required process for adjusting predicted crashes estimated by HSM's safety performance functions (SPFs) to local jurisdictions. LCFs for 18 facility types were calculated using data for the years 2008 to 2010. Additional variables were gathered by alternative data collection methods. Due to the difference

with HSM's crash proportion, Maryland's crash proportion was used to predict crash frequency and calculate LCFs. Maryland in general had fewer crashes than predicted crash frequency generated by HSM's SPFs. LCFs for 15 out of 18 facility types were less than 1.0. Especially, LCFs intersections were extremely low. Due to potential issues with unreported minor and property-damage-only crashes, the authors recommend using LCFs for fatal and injuries crashes where available. The pair-wise comparison of Maryland LCFs with LCFs of nine case studies showed statistically significant differences among states, providing grounds for jurisdiction-specific LCF development.

Another research paper discuss the approach to determine a statistically-reliable sample size for developing local calibration factors (LCFs) which was proposed to complement the Highway Safety Manual (HSM)'s sampling guidance. The HSM suggests a minimum sample size of 30-50 sites per facility type with at least 100 annual crashes. However, it fails to provide clear guidance on how to determine a minimum sample size to assure the statistical reliability of LCFs. The proposed approach, based on the finite population correction (FPC) factor, determined the minimum sample sizes by considering trade-offs among the desired error levels of the estimated LCFs, confidence levels, and sample standard deviations. The sample sizes by facility types were drawn, based on various statistical assumptions; then they were assured by the comparisons between FPC-based samples and the HSM-based samples. Estimated from the HSM-based sample sizes, the LCF values yielded inconsistent reliabilities depending on the facility types. In contrast, those from the samples by the FPC-based approach satisfied the desired reliabilities of the LCFs for all facility types.

Currently, we are in the second phase of Highway Safety Manual Project, which is for the freeways and the ramps. The student continues to participate in the HSM project and he is expected to write his doctoral dissertation from those research projects.

Another doctoral student is participating in Connected Vehicle technology related research. Morgan State University is a part of the Connected Vehicle Infrastructure (CVI) University Transportation Center (UTC) consortium with Virginia Polytechnic and State University and University of Virginia. As a member of consortium, the Morgan State University research teams are conducting three connected vehicle (CV) projects. As a result, the research team, including the doctoral student, presented a paper at 2015 TRB annual meeting.

One of the CV research projects was about the willingness-to-pay for the connected vehicle technology. Drivers' preferences (part-worth utility) and willingness-to-pay (WTP) for the CV technologies were analyzed and estimated by using the adaptive choice-based conjoint (ACBC) analysis, the newest conjoint analysis method. For the project, over 500 usable surveys were collected via online approach. Respondents were asked to choose among various CV technology bundles priced differently (e.g., collision prevention, roadway information system, etc.). It was

found that the acceptance level of the listed CV technologies was high, given the finding that an absolute majority of participants had the highest part-worth utilities for the most comprehensive technology bundle in each attribute. However, the comparison of the average importance of each attribute, including bundle prices, implies that prices will be an important constraint influencing the CV deployment rates. At the attribute level, "collision package" received the highest importance score among alternatives; that is safety benefits most appealing to drivers. The ACBC analysis seemed to mimic people's trade-offs for purchasing decision. The difference between WTP and self-explicated prices obtained before estimating preferences showed a statistical significance. That is, participants chose bundles by considering product attributes and prices. This finding also assures that the ACBC analysis is an appropriate method, compared to the past studies by using direct questioning methods. Finally, certain socioeconomic characteristics (i.e., drivers in 40's, African-Americans, lower educational attainment and a higher budget) were positively related to WTP.

There were other doctoral students produced by the Department of Transportation and Urban Infrastructure Studies. Their research projects were related to driving simulation, transit oriented development and highway safety. After graduation, many of them are working at transportation-consulting firms and state government transportation-related agencies.

6. Outcome Assessment on MSU Graduate Students Participating in NSF S-STEM Grants

As a premier minority-serving institution, Morgan is transitioning to a doctoral research university, which is a primary goal promoted in our ten-year strategic plan. To contribute to institutional goals, a scholarship program funded through the National Science Foundation was developed, which aims to significantly increase the financial support to engineering graduate students, especially underrepresented minority doctoral students. The objectives of *Doctoral Scholars in Engineering (DSiE)* consist of (1) Increasing access to the doctorate, especially for underrepresented minority students; (2) Improving doctoral degree completion and time to degree by relieving participants from full-time off-campus employment; (3) Improving support programs for doctoral students in the School of Engineering; and (4) Increasing the preparation for and placement of doctoral students in academic and research careers. Participants are recruited from enrolled students and new applicants to the civil, industrial, electrical, and transportation engineering departments, externally through conferences such as Black Engineer of the Year, and internally through Departmental Graduate Program Coordinators, electronic communiqués, and paper billboards. Applications are reviewed and evaluated by a faculty panel with representatives from each discipline. Doctoral students who participate in the program are selected, based on citizenship criteria, major, academic potential, professional accomplishments, motivation for future achievement and financial needs. Scholarship amount is $10,000 per year for each student. Table 1 below shows the results of initial recruitment and participant selection in the first semester.

Table 1: Applicant recruitment and selections (Year 1)

		Fall 2013		Spring 2014	
		Applicants	Selected Participants	Applicants	Selected Participants
Applicants	Female	5	3	2	2
	Male	13	4	7	1
Cumulative GPA		3.73	3.73	3.55	3.61
US Citizens		83%	100%	44%	33%
Current Doctoral Students		94%	100%	100%	100%
African American		78%	57%	89%	100%

During the first year of the scholarship, support was provided to a diverse group of students. The ten students selected in 2013 are compared to doctoral students in engineering (n=61) and all doctoral students at the university (n = 588). As shown in Table 2, DSiE participants were evenly distributed based on gender while maintaining the same minority percentage as the School of Engineering (70%).

Table 2: Comparison of DSiE Scholars and Morgan State University Demographics.

	Gender		**Ethnicity**	
	Male	**Female**	**Black**	**White**
DSiE Scholars	50%	50%	70%	30%
Engineering (Doctoral)	72%	28%	62%	5%
Morgan State (Doctoral)	38%	61%	74%	10%

The DSiE community utilizes existing student support structures in the School of Engineering while creating new opportunities for students to develop professionally. Students were provided with professional development opportunities, including several seminars and a workshop. The use of an Individual Development Plan has been shown to improve career outcomes for doctoral students and is promoted by many professional societies and funding agencies. Participants developed their own IDP using the tool at *www.myidp.sciencecareers.org*. This strategic planning tool allows students to use their skills, interests and values to set goals and identify career paths. While this tool is not specific to engineering, students think that the IDP exposed them to many things that should be considered for their careers. This process enabled the DSiE students to conduct a self-assessment of skills, interests and values related to careers in science and engineering. Participants are encouraged to set goals for career advancement, skills development, mentoring and project completion. These IDPs are used to identify their

professional development needs and select programming for the Seminar Series. At the end of each semester, students and their advisors provide joint feedback, on the students' accomplishments, goals, rate of progress, frequency of meeting with the advisor, and presentations/publications using a form developed by senior personnel. DSiE participants prepare or revise their IDPs each semester, share the IDP with their advisor or mentor, and received feedback from the DSiE investigator in their department. All students who have submitted an IDP found the usefulness of the plan as illustrated in Figure 2. Other seminars provided to students include *Graduate Student Expectations & Success* and *Grant Writing Fundamentals*. During Spring Break 2014, the DSiE team hosted a two-day hands-on research and communication workshop modeled after successful writing retreats at other institutions. The workshop was facilitated by the Academic Café (www.theacademiccafe.org). Workshop participants developed a research roadmap (Day 1), research plan (Day 1), presentation storyboard (Day 2), and research elevator speech (Day 2). Since most DSiE students are early in the course or dissertation proposal stage, the workshop was open to doctoral students in the School of Engineering and undergraduate and Master's research students in another S-STEM program. There were 21 attendees and the breakdown by academic classification is shown in Figure 3. Feedback about this workshop was overwhelmingly positive as shown in Figure 4.

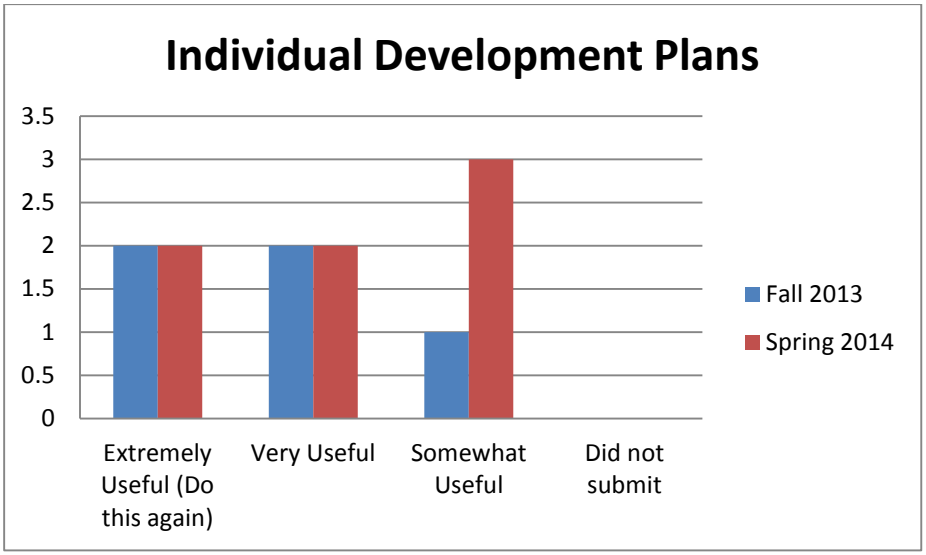

Figure 2: Students ratings on the usefulness of preparing IDPs.

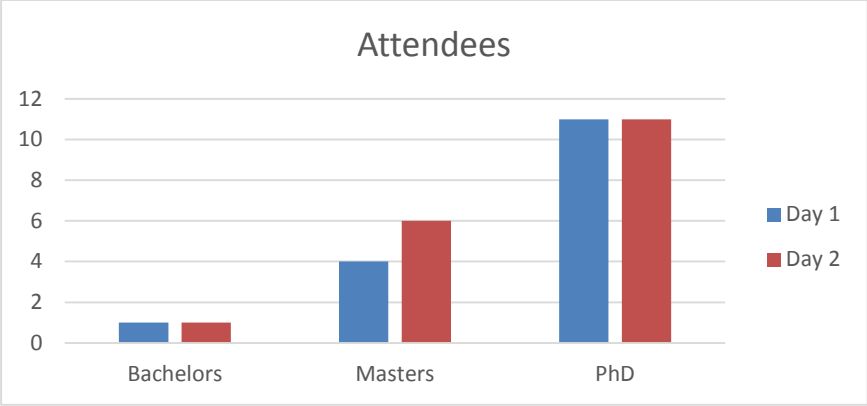

Figure 3: Workshop attendees by level.

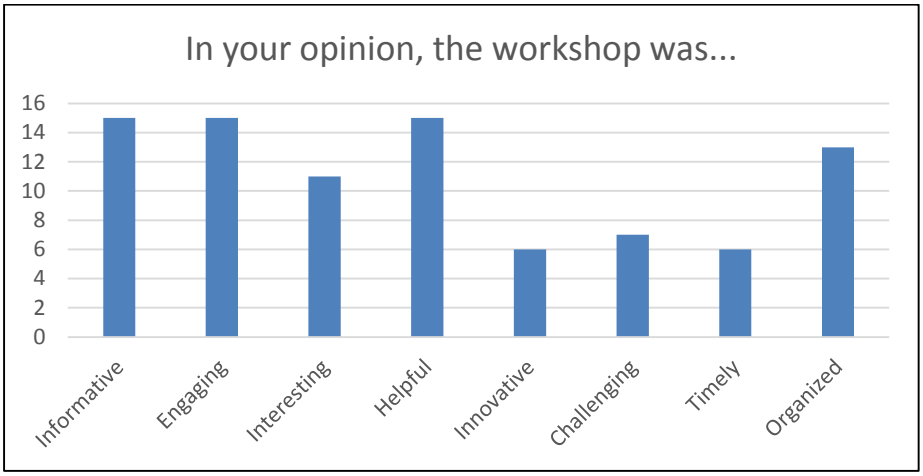

Figure 4: Student ratings of the Research and Communication Workshop

7. Concluding Remarks

The ability to conduct research or project is an important factor for the career development of engineering graduate students. Participation in an applied research project can effectively retain student's vigorous interests and enthusiasm in graduate study and enhance their problem-solving capability. Furthermore, involving graduate students in research projects with industry, Federal or governmental research centers and laboratories can significantly improve their teamwork skills and offer a better future employability on job market. Our experience in graduate education at MSU has convinced us that this graduate education setting can benefit these graduate students in their career-building path.

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References

1) Morgan State University, *Ten-Year Strategic Plan*, (available at www.morgan.edu), 2014.
2) Bailey, D.; Kohler, M.A.; Cole-Rhodes, A., "Using an ordinal ranking rule to find the top-performing Gaussian mixture models for language recognition", *Information Sciences and Systems (CISS)*, 2013, Page(s): 1-4. DOI: 10.1109/CISS.2013.6552299
3) William Emanuel, Corey Dickens, James Hunter and Albert Sweets, "Development Of A Performance Assessment Model; Using A System Engineering Methodology To Assess The Promotion Of Physical Activity At High Schools", *Review of Higher Education and Self Learning*, 2013.
4) John W. Evans, Guangming Chen, Jillian Y. Evans, James Bartos, "Development of acceleration factors for reliability testing of mechanical equipment", *International Journal of Quality Engineering and Technology*, Vol. 4, No. 3, pp 213--- 224, 2014. http://www.inderscience.com/info/inarticletoc.php?jcode=ijqet&year=2014&vol=4&is sue=3
5) Guangming Chen and John Evens, "Monte Carlo Methods in Reliability Physics", *Tutorial for Proceedings of IEEE 2013 International Reliability Physics Symposium*, Monterey, CA, April 14-18, 2013.
6) Mahdi Alimardani, Luis D Gallo, Guangming Chen, "Novel Uses of Anomaly Text Data for Reliability and Risk Mitigation", *Proceedings of Industrial and Systems Engineering Research Conference 2012*, Orlando, FL, May 19-23 2012.
7) Gerd M. Fischer, Oluseun Omotoso, Guangming Chen, "Availability Estimation for Facilities in Extreme Geographical Locations", *Proceedings of IEEE Reliability and Maintainability Symposium RAMS 2012: Securing Tomorrow's Future with Reliability and Maintainability*, Reno, Nevada, USA, January 23-26, 2012.
8) Guangming Chen and O. Omotoso, "Reliability Modeling of NASA McMurdo Antenna System with Engaging Graduate Students in Research", *Proceedings of 2012 HUIC International Conference on Math and Engineering Technology, Honolulu. Hawaii, July 31 - August 2, 2012.*
9) Ali Saboonchi and Guangming Chen, "Integration of NASA Systems Engineering Protocol into Software Defined Radio Technology Development", presented in *Industrial and Systems Engineering Research Conference 2012*, Orlando, FL, May 19-23 2012.
10) Guangming Chen, "Integration of Quality, Reliability and Systems Engineering into Student Training", Invited Presentation, *NASA Academy of Aerospace Quality (AAQ) Workshop and NASA Quality Leadership Forum (QLF*), Cape Canaveral, FL, March 15-18, 2011.
11) Oluseun Omotoso and G. Chen, "Application of Reliability Centered Maintenance and Failure Mode, Effect and Criticality Analysis in Preventive Maintenance Planning", *Proceedings of the 14th Annual International Conference on Industrial Engineering Theory, Application and Practice*, Anaheim, CA, Oct 18-21, 2009.
12) Carla D. Wheaden, (Advisers: Luis Gallo, John Evens and G. Chen), "The degradation of Radome panels due to probabilistic extreme wind events", student paper presented at *ASEE Mid-Atlantic Section Fall 2014 Conference*, Swarthmore, PA, November 14-15, 2014.