Research Conversations for Promoting Interdisciplinary Education, Research, and Faculty Collaboration

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ABSTRACT

It has been long recognized that one of the most important aspect of delivering high quality STEM education is to provide the students with an educational experience that includes a wide range of knowledge including not only engineering, science, and mathematics but also liberal arts education such as ergonomics (operation, safety, usability), business (economics, marketing, management, planning, corporate identity), aesthetics (form, visualization, style), and social, environmental, and cultural issues. In response to this need, the School of Engineering, Mathematics and Science (SEMS) at Robert Morris University (RMU) formed a Research and Outreach Center (ROC) in the year 2010. The center activities support the development of interdisciplinary curricula at the undergraduate level and encourage faculty and student engagement in interdisciplinary projects that could be later presented at the university, regional, national and international levels. SEMS-ROC demonstrates **diversity in research backgrounds** of the faculty and includes interdisciplinary interests of all three departments in the school. Research activities tend to cluster around several broad topic areas involving faculty from across SEMS disciplines as well as in some cases, from other Schools at the institution along with other institutions around the country.

One of the initiatives undertaken at SEMS-ROC to break down the departmental-level and school-level silos and encourage to nurture the development of interdisciplinary work environment was the "***Research Conversations***" meetings. These meetings were held in an informal way to provide a platform for faculty to share their own research expertise with their peers and to learn from each other. This peer-to-peer contact also had a positive effect of finding common interests, explore overlapping areas of research, forming collegial relationships that blossomed later into multidisciplinary teams. Several research project ideas came forward through this knowledge diffusion which led to grant applications, the development of ideas for undergraduate curricula, active research programs and subsequent conference and journal paper publications. Some of these conversations were also summarized and published as ***Research Highlights*** newsletter after an editorial process to promote and advertise the research conducted within the university.

Interdisciplinary approach for research has also been applied to education at the authors' institution. Two undergraduate course curricula have been have been redeveloped to incorporate significant project elements and engaged learning tools to enhance student learning and experience. One engineering course dealing with product and tool design is delivered in collaboration with Media Arts and Marketing departments. The other course in software engineering is now taught through discussions of assigned case studies and scenarios drawn from industry.

This paper summarizes the design of ***Research Conversations*** meetings and the new interdisciplinary curricula and presents the impact it has had on the development of interdisciplinary work culture at RMU.

1. Introduction

It has been recognized that the current generation of STEM graduates need the skills and knowledge that would enable them to deal with the complex, interdisciplinary problems they would face as they graduate from college and enter the workforce [1]. Broad-based and interdisciplinary knowledge is not easy to come by and it is the most difficult to deliver in class rooms. In order to achieve these goals, the first key step would be to have faculty well-trained and well-versed in the field of interdisciplinary work and collaboration. In addition, the institution could support a “teacher-scholar” model to establish proper relationship and balance between instruction and research, as the commitment to undergraduate education is a crucial institutional priority. Intellectual energy comes not only from faculty talking with able students but also from faculty talking with fellow faculty. Some of this activity represents the spirit of creativity and curiosity that supports both scholarship and teaching. These major efforts are needed for faculty development to accomplish this educational challenge [2]. Faculty development and mentorship programs are definitely important to prepare faculty members for their academic roles including teaching, research, administration, writing and career management [3]. Faculty development program in this case included amongst others the development of activities for interdisciplinary collaborations to forge partnerships with faculty from different disciplines and to design educational initiatives that enabled students from different majors to work collaboratively on entrepreneurial projects.

Many faculty professional development effort rely on the knowledge transmission model – the so-called “develop-disseminate model” in which individuals or small groups develop new curricular materials and strategies through significant effort and then try to convince others to use them [4]. The work is then disseminated through professional societies like ASEE, Frontiers in Education (FIE) conference sessions or workshops or through campus based workshops [5]. This knowledge transmission model has limited effectiveness because of its one-shot, one-size-fits-all, just-in-case training approach fails to address local difference and needs [6]. Another problem with this model is that there is no follow up activity and therefore the extent of the change and sustainability of changes is low. In some universities there are programs or centers made available for faculty development to enhance collaboration. However historical research suggests that such centers are not able to deliver high impact in faculty development [7]. This is mainly because the faculty are not able to see the linkage between the content of their course and the material being presented at these centers. More sustained and long term efforts are needed to change instructor’s attitude, knowledge, teaching skills and behavior [8]. Active and engaged learning methods have been tested and found to be more effective in enhancing teaching. However, their adoption by faculty has been very slow leading to stalled innovations in STEM education [9, 10].

In the present work a Research and Outreach Center (ROC) was created at the author’s institution – Robert Morris University (RMU) that has implemented two mechanisms to enhance faculty collaboration across the disciplines and create a platform for STEM education innovation. The hypothesis in creating these mechanisms was that more natural, less formal faculty meetings would enhance common interactions of the faculty with each other promoting knowledge transfer and the development of multi-disciplinary research teams as well as the conceptualization, design and development of interdisciplinary curricula. This type of collaboration and interaction is especially important for small and medium-sized schools and universities where undergraduate / graduate teaching accounts for a major portion of the faculty workload. Thus the paper describes the interdisciplinary research collaborations as well as the development of interdisciplinary educational curricula and their role in reaching educational objectives of the department, the school and the institution.

Following section gives brief information about ROC and the subsequent sections describe the mechanisms implemented to trigger and sustain faculty development over a longer period of time.

2. Research and Outreach Center (ROC): Mechanisms for Interdisciplinary Collaboration

The Research and Outreach Center (ROC) was established in 2010 by the SEMS Dean to connect SEMS faculty and students with the region, the nation and the globe, demonstrate diversity and interdisciplinary interests of all three departments with the school. ROC creates a stimulating environment for faculty and staff to achieve their career goals and professional development. Professional development of the faculty is achieved through research conversations meetings (described more fully in the next section), summer research experiences, professional society training activities and technical/scientific conferences. From an institutional strategic point of view, the establishment of SEMS ROC and its activities fulfil the goal of promoting the teacher-scholar model adopted by the institution for the faculty by promoting the following tasks:

- A commitment to high quality teaching,
- Pursuing active programs of research and scholarship,
- Incorporating their research into their teaching,
- Undertaking activities to assure currency in their field, and
- Including students in faculty research projects where appropriate.

To achieve these tasks ROC has been active in the development of collaborative research proposals within author's institution as well as across institutions. The research outcomes are published monthly in 'Research Highlights' newsletter. ROC provides appropriate proposal and funding information for the faculty to facilitate proposal preparation process and finally, The faculty is encouraged to incorporate their academic research in their teaching to enhance student learning. Academic excellence is promoted via conducting research supported by industry partners, foundations, other research institutions and government agencies.

3. *Research Conversations* Meetings

Two mechanisms that triggered interdisciplinary collaboration, faculty interaction, education and research at ROC were mentioned in the past section: one was *Research Conversations* meetings and the other was publishing *Research Highlights* newsletter. More information on *Research Conversations* meetings is given in this section while additional details of *Research Highlights* newsletter are given in the following section.

3.1 Meeting Format

Research Conversations is an informal meeting with no agenda and no minutes kept. The location is a conference room with a table positioned in a way so that people are able to informally talk to each other. There is computer and projector for the speaker's convenience. The meeting is scheduled on Fridays, once per month, of one hour duration. The format is 20 minutes for quick lunch and meet / greet / introductions, followed by 20 minutes talk and then 20 minutes open discussion session. People may stay back for more detailed discussions if they would like to do so. The speakers are solicited by the organizers and has no formal review process for selection. The solicitation is either by invitation or via general call to faculty to deliver the talk. Last year the invitation was extended to faculty outside of SEMS.

3.2 Meeting Rationale

Small private schools are not able to enjoy the benefits of having a large pool of expert faculty members within one department to collaborate with each other and develop serious research ideas and proposals. In the current environment of very high competition, it becomes very difficult to attract research funding to smaller schools that have few faculty and limited resources. Therefore, it was envisaged that '*Research Conversations*' meeting will bring together faculty from engineering, science and mathematics departments on one platform to share their research interest and to see if there were any areas of overlap for collaborative work. Thus the primary objectives for organizing these meetings were as follows:

- Get to know each other better in an informal setting
- Learn about each other's research interest, experience, background, skills and facilities
- Find common interests
- Explore overlapping research areas
- Promote knowledge diffusion
- Build and strengthen personal bonds
- Develop joint research proposals
- Share the experiences of competing for the funding – good and bad!

In addition, research administrators may advise the faculty at this forum of the following:

- Share information related to research funding opportunities, agencies and application processes
- Provide information of the university's internal application process
- Budget development, budget justification and budget narrative
- Intellectual Property (IP) matters
- Institutional Review Board (IRB) matters
- Publicizing research activities both within and outside university community

3.3 Meeting Topics

The Research Conversations meetings have now taken place regularly over the past five semesters starting Fall 2013 (two and half years to date). Some of the topics discussed in these meetings are summarized below:

- Alternative energy and photovoltaic cells
- Energy efficient manufacturing of steel products
- Biomechanics, brain damage, concussion assessment
- Virtual reality games for nursing education
- Pesticides and their effects on ecosystems
- Statistics, 3D calculus, linear algebra
- Additive manufacturing, laser processing
- Vibrations, mechanical systems, marine biological systems
- Soil analysis and acid mine water damage remediation
- Pedagogy in STEM education

Faculty from all across the board at this university have been attending these meetings as their schedules permitted it. The attendance has been in the range of 12 – 24 people at each meeting, average being 15 - 16 folks. The invitation to attend meetings is sent to all faculty in the university.

3.4 Meeting Outcomes

The outcomes of these meetings have been really positive, we are happy to report. People have not only enjoyed the talks but also getting to know each other better and enjoying the conversations and camaraderie. There have been some tangible outcomes too. Based on the faculty interaction at the Research Conversations meetings, several projects have been proposed for interdisciplinary research. A series of meetings have taken place subsequently to develop the ideas further and the ideas have evolved into a stage where full scale proposals for NSF or other funding agencies could be sought. Some examples of the major research proposals that are spawned out of these sessions or existing proposals that were enhanced because of constructive interaction are given below:

- Collaborative work in alternative energy and manufacturing – chemistry, industrial engineering, materials science, advanced manufacturing and mechanical engineering
- Improving undergraduate biology education – biology, mechanics, statics, finite element modeling and materials engineering
- Developing software for teaching aseptic technique to nursing / health care provider students

Faculty from business school, education and social sciences school, and communications and information systems school have been able to interact with the school of engineering, mathematics and science faculty in these meetings bringing different perspectives at the discussion table. The format of the Research Conversations meeting was liked by many attending and based on SEMS experience, the School of Communications and Information Systems (SCIS) are planning to start similar meetings in their own school to break down the departmental silos including media arts, communications, computer and information systems, English, and organizational leadership.

4. *Research Highlights* Newsletter

Several *Research Highlights* newsletters were published based on the presentations and discussions that happened in the Research Conversations meetings. Some topics on which Research Highlights newsletters were published are given below (in chronological order):

- Nov. 2013: Vol. 1, No. 1, A computer model for optimizing the location of natural gas fueling
- Dec. 2013: Vol. 1, No. 2, Biomedical engineers design concussion detection system for grade school athletes
- Jan. 2014: Vol. 1, No. 3, Energy efficient processes for steel products: opportunities and critical challenges,
- Feb. 2014: Vol. 1, No. 4, Simulation-based energy analysis of a linear concentrating photovoltaic system,
- Mar. 2014: Vol. 1, No. 5, SEMS ROC Status Report: Research by The Numbers,
- Aug. 2014: Vol. 1, No. 6, Research Status Report 2013-14
- Sept. 2014: Vol. 1, No. 7, Additive manufacturing research for product design and development in fluid condition,
- Oct. 2014: Vol. 1, No. 8, Improving conceptual understanding of multivariable calculus through visualization using CalcPlot3D
- Nov. 2014: Vol. 1, No. 9, Understanding brain injury and disease through biomechanics and biohybrid microdevices
- Jan. 2015: Vol. 2, No. 1, A dynamic model for scheduling of elective patients with respect to current surgical resources and downstream units
- May 2015: Vol. 2, No. 2, A network model for statistical analysis of disease spread in host population
- June 2015: Vol. 2, No. 3, Alternative expectation equations for nonnegative continuous random variable
- Nov. 2015: Vol. 2, No. 4, Functional equations defined on abstract structures,
- Dec. 2015: Vol. 2, No. 5, Vibration of discrete and continuous systems,
- Jan. 2016: Vol. 2, No. 6, Soil microflora, elemental and genetic analysis in fabricated soils

A one-page standard format was prepared on the *Research Highlights* newsletter where the story was told in as simple terms as possible. An effort was made to make the connections between the research conducted and everyday life of the community so that people could immediately appreciate what was being done at the university. The newsletter was displayed at the display boards within SEMS, uploaded on ROC's research page, distributed to faculty and staff, given to the industrial advisory board members, and included as a handout within the potential and new student welcome packages. Recently, a list of research projects available with different faculty members was prepared and this list is shared with the students as well so that they have a wide choice of project topics for their honors or capstone research experience.

5. Interdisciplinary Educational Innovations

One of the authors has been working closely for the past ten years with faculty from Media Arts and Marketing departments to develop and implement a highly successful product and tool design interdisciplinary class while the other author has significant background in all three disciplines within SEMS. Basic idea here is that new product development is a truly interdisciplinary work that encompasses aesthetics, engineering, arts, business, marketing, sales, strategic vision and communication topics. Many papers have been published based on this extensive work and thus it will not be discussed any further in this paper. Interested readers are welcome to follow up with the cited references here [11, 12, 13].

We will be presenting another example of educational innovation which includes applying engaged and active learning methods to enhance educational experience in software verification and validation (SV&V) using case studies, class exercises and role play videos. The faculty involved in this project are from SEMS as well as SCIS. The author's university is collaborating with four industry partners that are either large software companies or companies with large software development activities. These partners are: Eaton Electrical Corporation, ServiceLink, PNC Bank, and JDA Software Group. Their areas of expertise are in electrical systems, mortgage, intelligent pricing, and revenue management. The research work conducted through consultation and collaboration with these industry partners contributes significantly in the following activities:

- Critically review and identify knowledge gaps in SV&V courseware,
- Assist in developing course modules,
- Deliver expert lecture sessions to undergraduate students at partner universities if requested,
- Deliver training programs to industry practitioners,
- Assess student/trainee learning.

RMU is also collaborating with two categories of academic partners: *Development Academic Partners* (assist in developing course modules – they are Virginia State University, and Milwaukee School of Engineering) and *Implementation Academic Partners* (assist in delivering course modules and providing delivery feedback – they are Embry-Riddle Aeronautical University, Montana Technical University, University of Michigan-Dearborn, Fairfield University, Auburn University, East Carolina University, Kennesaw State University (Georgia), Bowie State University, and Clarion University). These academic partners offer one or more bachelor degrees in Software Engineering, Computer Science, Computer Engineering, and Electrical Engineering. These partners also share strong desire to strengthen their programs.

We have developed several SV&V case studies [14] for educational purposes to demonstrate software development methods and processes. Case study education provides students with a record of technical and/or business issues that actually has been faced by managers, together with surrounding facts, opinions, and prejudices upon which management decisions have to depend. Case studies were used to help students (1) understand complex and complicated issues and describe interrelated processes; (2) discuss policy- and decision-making ideologies that either are politically or socially charged; and (3) engage in informative and focused classroom discussion. Specifically, they help students develop problem-solving, critical-reasoning, and analytical skills, all of which are valuable tools that prepare students to make better decisions and become better students and, ultimately, better employees. The results from this work has recently been reported in journals [5, 15].

From a pedagogical point of view, the case study based education was found to be broad in terms of its effectiveness in educational outcomes and it has been suggested that it can be used to deliver all eleven ***'a' through 'k'*** criteria of ABET accreditation [16]. The flexibility of case studies coupled with the richness of data and information analysis, decision making education and conflict resolution results in strong links with ABET criteria. Kauffman et al [17] have mapped case study outcomes to the ABET criteria for engineering economy case studies. Such analysis is adopted here for case studies in software engineering as shown in Table 1.

Table 1. Case study analysis in software engineering and its relation to ABET criteria.

ABET Criterion	Software Engineering Case Study Analysis
(b) An ability to design and conduct experiments as well as to analyze and interpret data	Case studies require students to find or develop the important information and ignore data that is not relevant
(c) an ability to design a system, component or a process to meet desired needs	Case studies require students to confront complex issues such as trade off analysis along with time, resource and risk management decisions
(d) an ability to function on multi-disciplinary teams	Case studies require students to solve case problems, they must also learn to negotiate and understand different viewpoints prior to their decision making
(e) An ability to identify, formulate, and solve engineering problems	Case studies require students to identify important data and ignore irrelevant data, actively look for missing data or make appropriate assumption and use mathematical / computer simulation based tools to solve engineering problems
(g) an ability to communicate effectively	Case studies require students to make presentation of case analysis results in both oral and written formats
(h) the broad education necessary to understand the impact of engineering solutions in a societal and global context	Critical thinking required by case study analysis promotes systems thinking related to larger impact of decision alternatives
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	Case studies require students to learn and apply contemporary engineering tools to solve case problems

Pedagogical outcomes that are relevant for software verification and validation have been identified at the author's institution based on ABET Criterion 3 outcomes assessment. The relationships between the specified ABET outcomes for this course and their correspondence with the revised Bloom's taxonomy for STEM disciplines is shown in Table 2. The seven levels (taxa) of conceptual and procedural knowledge and skills taxonomy proposed by Girgis [18] mentioned in Table 2 are defined as follows:

Taxa I - Pre-knowledge Conceptual Experiences: hands-on laboratory experiences via demonstrations, physical models, practical applications to demonstrate, visualize and observe basic concepts
Taxa II - Basic Conceptual Knowledge: learning, understanding, memorizing basic engineering concepts, definitions, terms, symbols, theories, laws and equations
Taxa III - Applied Conceptual Knowledge: solving simple concept-based problems and conducting related laboratory experiments
Taxa IV - Procedural Knowledge: working knowledge of solving multi-concept engineering problems
Taxa V - Advanced Knowledge and Analytical Skills: inter-domain and open-ended problem solving skills
Taxa VI - Project-based Knowledge: creative, conceptual, analytical, design, manufacturing and management skills
Taxa VII - Professional Engineering Knowledge and Practices: life-long learning experiences, skills and practices

Table 2. Expected pedagogical outcomes for software V&V course at RMU.

Applicable ABET Criterion 3 Learning Outcomes for Software V&V course at RMU	**Conceptual and procedural knowledge taxonomy based on revised Bloom's taxonomy for STEM Disciplines** [17, 19]
b. An ability to design and conduct experiments, and analyze and interpret data	I & III
e. An ability to identify, formulate, and solve engineering problems	II, IV & V
f. An understanding of professional and ethical responsibilities	V & VII
g. An ability to communicate effectively	III, IV & V
h. Broad education necessary to understand the impact of engineering solutions in a global and societal context	VI
i. Recognition of the need for and an ability to engage in life-long learning.	VII
j. A knowledge of contemporary issues	V & VI
k. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	VI & VII

It is clear from the information presented in Tables 1 and 2 that it is possible to evaluate student learning outcomes ***b, g, h*** and ***k*** using the case study based educational tools.

Thus through a vibrant academia-industry partnership and academic research this project funded by a NSF-TUES grant has been developed, delivered, and disseminated. About forty two delivery hours of active learning tools which includes case studies, class exercises, and video case studies in specific SV&V topics viz. *requirements engineering, software reviews, configuration management,* and *software testing.* As of date, the active learning tools have been disseminated through a workshop to eleven universities and five industry partners. In addition the tools have been shared with nine other institutions that were not able to attend the workshop. The dissemination has also taken place through conference and journal publications.

6. Summary

Faculty interaction and collaboration has been strongly encouraged at the author's institution through a series of Research Conversations meetings and the subsequent publication of Research Highlights newsletters. These efforts has brought together faculty from STEM disciplines as well as art, marketing, business, communication and education to work together and explore opportunities for interdisciplinary collaboration, research and course and curriculum development. The sharing of knowledge across disciplines in an informal manner helped faculty understand each other's areas of research interests and skills and subsequently build on them to generate research projects and proposals. Several significant grant proposals have been developed and submitted and new projects are coming on board. Interdisciplinary curricula are being designed and educational innovations in STEM are being achieved especially in the areas of product and tool design and software verification and validation. Interdisciplinary biology curricula and laboratories are also expected to be developed in near future. A detailed case study of developing new curricula and active learning tools in the area of software verification and validation is presented that significantly enhances student learning experience.

Acknowledgment

The author wishes to acknowledge Dr. Maria Kalevitch, Dean of the school of Engineering, mathematics and Science at the author's institution for her constant support and encouragement and also for reviewing the manuscript.

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