



Conducting State-of-the-art Research in an Institution with a Strong Undergraduate Education Focus

Dr. Yusuf A Mehta, Rowan University

Dr. Mehta is an associate professor at the Department of Civil and Environmental Engineering at Rowan University. Dr. Mehta has extensive experience in teaching pavement materials and pavement systems. Dr. Mehta has published several technical and educational papers in leading professional organizations.

Dr. Ralph Alan Dusseau P.E., Rowan University

Dr. Ralph Alan Dusseau, P.E., is professor and founding chair of the Department of Civil and Environmental Engineering at Rowan University. Before coming to Rowan University in August 1995, Dr. Dusseau was an assistant and associate professor in the Department of Civil and Environmental Engineering at Wayne State University from 1985 to 1995. Dr. Dusseau received his bachelor's, master's, and doctoral degrees from Michigan State University in 1978, 1982, and 1985, respectively. Dr. Dusseau's area of expertise is bridge engineering with an emphasis on seismic analysis of bridge structures.

Dr. Ravi P. Ramachandran, Rowan University

Dr. Ravi P. Ramachandran received his bachelor's degree in Engineering with great distinction from Concordia University in 1984 and his master's degree in Engineering from McGill University in 1986. He earned his Ph.D. degree from McGill University in 1990. From October 1990 to December 1992, he worked at the Speech Research Department at AT&T Bell Laboratories. From 1993 to 1997, he was a research assistant professor at Rutgers University. He was also a senior speech scientist at T-Netix from 1996 to August 1997. Since September 1997, he has worked in the Department of Electrical and Computer Engineering at Rowan University and been a professor since September 2006. He has served as a consultant to T-Netix, Avenir Inc. and Motorola. From September 2002 to September 2005, he was an associate editor for the IEEE Transactions on Speech and Audio Processing and was on the Speech Technical Committee of the Signal Processing society. Since September 2000, he has been on the Editorial Board of the IEEE Circuits and Systems Magazine. Since May 2002, he has been on the Digital Signal Processing Technical Committee for the Circuits and Systems society. His research interests are in digital signal processing, speech processing, pattern recognition and filter design.

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The author is teaching at Rowan University, which is primarily focused on undergraduate education with a small M.S. program in Civil Engineering. The typical cohort of full-time funded graduate students in Civil Engineering is around 3-4 per year. In the undergraduate program, each student in the junior and senior years has to take two clinic credits per semester. In each of these four semesters, the students work on industry or grant funded project. The typical workload for a full-time faculty member is nine credits, which includes supervision of three to four clinic projects, with 3-4 students in each clinic project. The lack of a doctoral program usually could be a big limitation for faculty members to attract large research funding that spans over 3 to 4 years. This may be due to lack of continuity of the project between the students and the need to retrain students during the different phases of a project. The author has received research funding that spans 3-4 years. To ensure that project deliverables are met and there is continuity throughout the project the author recruited undergraduate students in the junior year and got them involved in the project for the next two years alongside a graduate student. The undergraduate students not only assist in testing, but also in writing reports, making presentations to sponsors and writing papers in prestigious journals and conferences. After two years, the undergraduate student had two years' experience alongside the graduate student who will soon or has already graduated. The undergraduate student finishes his/her baccalaureate and is ready to start graduate studies and work on the project where the previous graduate student left-off. This ensures that the continuity is maintained and there is very little downtime when the new student starts as a graduate student. This paper presents the successes and challenges facing the author with ensuring a seamless integration between the undergraduate and graduate student without affecting the project outcomes. This paper will help faculty members in peer institutions who are seeking to be active in research.

Introduction

The College of Engineering is a predominantly undergraduate institution with a growing Master of Science program. The college of engineering offers degrees in four programs, Chemical engineering, Civil and Environmental engineering, Electrical and Computer engineering, and Mechanical engineering. The typical enrollment in the undergraduate degree in the college of engineering is approximately 500 students evenly distributed among four programs. The typical enrollment in the Master of Science program is approximately three to six full time students and additional five to ten part time graduate students.

Junior and Senior Engineering Clinics

One of the key hallmarks of the undergraduate curriculum is the junior and senior clinics. The junior and senior students are required to take two credits of clinics each semester, for a total of eight credits. In these clinics, a multidisciplinary group of undergraduate students work on funded or unfunded government, industry or faculty initiated projects. The projects are supervised by a single faculty member, also called the project manager, or a group of faculty members. Each clinic team consists of 3-4 students, and they could be from each of the four programs. These students could be working closely with full time graduate students working on

the project. All the clinic students have five and a half hours of “class-time” allocated per week. The deliverables of the clinic are project dependent however they include the following at a minimum:

- 1) Mid-term presentation to the project manager and other faculty members associated with the project
- 2) Final presentation to the faculty members in the department and to the sponsors

In addition, clinic students with or without the assistance of graduate students may write quarterly reports, visit the sponsor and make presentations, and write peer reviewed conference proceedings and journal papers. The overall objectives of the clinic and the grading guidelines are shown below. These objectives and the grading guidelines were developed by a committee of faculty members and are applicable to all engineering clinics. The author has adopted these objectives and grading guidelines. In addition to the overall clinic objectives, project specific objectives were introduced.

Engineering Clinic Objectives:

http://www.rowan.edu/open/colleges/engineering/current_students/course_material/

At the conclusion of the course, students will

- (i) Demonstrate expanded knowledge of the general practices and the profession of engineering through immersion in an engineering project environment of moderate to high complexity.
- (ii) Demonstrate an ability to work effectively in a multidisciplinary team.
- (iii) Demonstrate acquisition of new technology skills through use or development of appropriate computer hardware, software, and/or instrumentation.
- (iv) Demonstrate business and entrepreneurial skills which may include developing a business plan, market plan, venture plan, or other approved instrument.
- (v) Demonstrate effective use of project and personnel management techniques.
- (vi) Identify and meet customer needs.
- (vii) Integrate engineering professionalism, ethics, and the environmental in their work and as it relates to the context of engineering in society.
- (viii) Demonstrate improved communication skills including written, oral, and multimedia. This may include both patent and literature searches as well as writing a patent disclosure for novel work.

Common Grading Guidelines for Jr. /Sr. Engineering Clinic

The following (Table 1) are general guidelines that are used for establishing grades for the Junior/Senior Engineering Clinic. As mentioned earlier, these guidelines were developed by the clinic committee and adopted by the author.

Objective

The benefits of undergraduate research and on the faculty mentors have been extensively documented, however challenges to conducting research in a predominantly undergraduate institution remain [1]. The objective of the paper is to present how the author has effectively utilized the clinic program to establish the construction materials research program at Rowan University. The process of establishing a successful research program presented here is not

unique and has been replicated by other faculty members, including the co-author, in the college of engineering. In this paper, the author has attempted to document and present the positive impact that the undergraduate research experience has on developing a research program in an institution with a strong education focus.

Table 1. Grading guidelines developed by clinic committee

<i>Grade</i>	<i>Guidelines</i>
A	<ul style="list-style-type: none"> • Exceed Expectations • Take charge of the project and generate tasks from goals and objectives. • Think independently, ask questions and make suggestions. • Develop original solutions by combining theory and/or analytical techniques that demonstrate a mastery of engineering science and/or design principles from one or more supporting engineering courses. • Demonstrate the ability to engage in lifelong learning by applying engineering science and/or design principles that are not covered in your supporting engineering courses. • Complete all project deliverables and objectives. • Effectively communicate (via written, oral, engineering drawings, etc.) project deliverables to your project manager and/or external sponsor. • Exhibit consistently strong team and individual performance in terms of project deliverables and objectives as well as laboratory safety, team skills, record keeping, punctuality, etc.
B	<ul style="list-style-type: none"> • Take charge of the project and does all of the work that you are asked to do. • Ask questions and make suggestions. • Develop solutions by applying theory and/or analytical techniques that demonstrate a mastery of engineering science and/or design principles from one or more supporting engineering courses. • Complete all project deliverables and objectives. • Effectively communicate (via written, oral, engineering drawings, etc.) project deliverables to your project manager and/or external sponsor. • Exhibit strong team and individual performance in terms of project deliverables and objectives as well as laboratory safety, team skills, record keeping, punctuality, etc.
C	<ul style="list-style-type: none"> • Do all of the work you are asked to do. • Develop solutions by applying theory and/or analytical techniques. • Complete all project deliverables and objectives. • Communicate (via written, oral, engineering drawings, etc.) project deliverables to your project manager and/or external sponsor. • Exhibit average team and individual performance in terms of project deliverables and objectives as well as laboratory safety, team skills, record keeping, punctuality, etc.
D	<ul style="list-style-type: none"> • Do some of the work that you are asked to do. • Complete some of the project deliverables and objectives. • Ineffectively communicate (via written, oral, engineering drawings, etc.) project deliverables to your project manager and/or external sponsor. • Exhibit poor team and individual performance in terms of project deliverables and objectives as well as laboratory safety, team skills, record keeping, punctuality, etc.
F	Do very little. Don't show up.

Graduate Program

The full time M.S program funded by a research project is typically one and one-half to two years long. During the duration of the program, the graduate students work closely with clinic team members. The graduate students may train the clinic students in various experimental procedures or analysis techniques that will help achieve the goal of the project. The graduate research assistants are required to do a total of thirty credits with at least six credits of thesis and submit a thesis as part of the graduation requirements.

Transition from Undergraduate to Graduate Program

The research projects supervised by the Principal Investigator are approximately one to four years long. The projects that are more than two years long will require overlapping of graduate students to ensure that the project deliverables are met in a timely fashion.

A smooth transition between graduate students in the middle of a three or four yearlong project is necessary to prevent a crippling effect on the project especially if the incoming graduate student is new to the project. Table 2 shows a typical timeline on how the undergraduate student (X) is transitioned from undergraduate to graduate student within a research project A. The clinic students that continue on the same project through the junior and senior year (four semesters) help maintain the continuity and the productivity. By the time the seniors are ready to graduate, they have a similar level of experience as a graduate student in a given project.

At the end of three years, there could be potentially two graduate students stemming from their work on clinic work from research project A. The second graduate student (Y) may not necessarily work on research project A, but may work on a new research project B. This helps increase productivity on the second research project from the first semester itself. The clinic experience has also led students to pursue graduate studies in other top engineering schools in the nation.

International Graduate Students

In the last four years, international graduate students have received research funding to work on pavement related research projects. In the first semester of their arrival, they are required to work with clinic groups. This forces the new international students to apply team leadership skills while navigating through the project under the guidance of the author. These skills in their early stages of arrival in the country are very helpful in their developing self-confidence, communication and presentation skills. These skills have eventually translated in their finding a job soon after their graduation. On the other hand, the interaction of junior-senior clinic students with international graduate students is also an enriching experience for the students. The clinic students get a better understanding of the different culture and better communication skills.

Presentation venues for undergraduate and graduate students

Table 3 shows the typical local, regional, or national forums where undergraduate and graduate students present during the calendar year. The author makes every effort to encourage students

to present and fund their travel to the conference. However, if that is not possible, the author makes the presentation at these forums by himself. In addition, the undergraduate and graduate students attend the progress report meetings as required by the sponsor. The graduate students with assistance from clinic students take the lead in writing journal publications and conference proceedings. In the past twelve year, the author has published in 23 peer reviewed journals and 50 peer reviewed conference proceedings related to transportation research. The author has also been the primary thesis adviser of twelve students and currently has three students.

Table 2. A typical timeline for transition from clinic to graduate student during a research project

Year	Timeline	Fall semester	Spring semester	Summer semester
1	New research project A – Year 1	Clinic group I consisting of juniors and seniors work on research project A. <i>All the team members may not be the same between the fall and spring semester.</i>		Involve one junior student (X) from clinic group I to work in the summer on research project A
2	Research Project A – Year 2	Clinic group II of juniors and seniors work on research project A are now lead by student X (now a senior).		<ul style="list-style-type: none"> • Student X starts graduate school funded on research project A • Involve one junior student (Y) from clinic group II to work in the summer on research project A
			Student X applies for grad school at Rowan University.	
3	Research Project A – Year 3	Clinic group III of juniors and seniors now under the supervision of the graduate student X and also include now a senior student Y.		<ul style="list-style-type: none"> • Student Y starts graduate school funded on research project A or another research project B. • Student X still continues on research project A until he /she finishes thesis.
			Student Y applies for grad school at Rowan.	
4	Research Project B – Year 1	Clinic group IV of juniors and seniors now under the supervision of the graduate student Y.		<ul style="list-style-type: none"> • Involve one junior student (Z) from clinic group IV to work in the summer on research project B. • Student Y still continues on research project A until he /she finishes thesis.
	Research Project A – Year 4	Graduate student X only to complete the project.		

Table 3. Presentation venues

Venue	Undergraduate clinic students	Graduate students
Fall		
New Jersey DOT research showcase, Trenton. (month of October)	Poster	Podium or poster with undergraduate students
New England Asphalt User Producer Groups Fall meeting (location rotating) (month of October)	Poster or podium presentation	
Delaware valley engineers week council undergraduate paper (Monday of November before Thanksgiving)	Submit paper	
Spring		
Transportation Research Board, Washington DC (month of January)	Poster and/or podium presentation	
Delaware Valley Engineers Week Council awards banquet (Engineer's week in February)	Poster (if clinic team is selected for award)	
Solid waste conference (Philadelphia) (month of March)	Poster or podium presentation	
Science Technology, Engineering and Math – Rowan university Symposium (third Friday of April)	Poster presentation	
Summer		
ASCE conferences, such as Geohunan, Geoshanghai, and Transportation and Development Institute, and Bearing Capacity of Roads Railways and Airfield	Poster or podium presentation	

Another example of transition from undergraduate to graduate program in Structural engineering

Rowan University received a 4-year \$1 million research contract from the Delaware River Port Authority (DRPA) in 2000 to study three bridges over the Delaware River that are owned by DRPA. The Junior/Senior Clinic at Rowan was the single biggest selling point for securing this research contract. In addition to the research that was to be conducted, DRPA wanted the project to include two key components: significant undergraduate involvement and continuity from the undergraduate to graduate levels. The sponsor wanted to avoid using only master's degree students with the annual turnover of talent and loss of productivity that occurs with such an arrangement. Using the Junior/Senior Clinics, we were able to involve 6 to 9 undergraduate students per semester in the DRPA project with some (2 to 4) of these students continuing on to the master level while still working on the project. Thus, approximately half of the

undergraduate students involved in the DRPA project continued on to complete their master's degree.

Example of an Electrical and Computer Engineering Student

Students in Electrical and Computer Engineering (ECE) also fit the timeline provided by Table 2. They are trained during the undergraduate clinic experience and make a very smooth transition to graduate school. In fact, a significant proportion of ECE students proceed to graduate school either at Rowan or at other schools [2]. One example of a clinic to graduate school experience is given as follows:

1. The student started in the senior year with a vision to do a Master's thesis in biometrics. The student spent the junior year in out-of-discipline clinic projects and acquired much software skills for specific applications. Biometrics requires software skills and hence, the junior level experience was very helpful to the student.
2. During the fall semester of the senior year, the student developed a face recognition module for Freshman students that is currently taught in the Freshman Clinic course at Rowan and can be used in any Introduction to Engineering course at other schools [3]. This project helped the student learn the concepts involved in biometric system design, biometric system testing and mitigating performance loss due to mismatched training and testing conditions. The student achieved a MATLAB implementation of a face recognition system and wrote a lab manual such that freshman students can appreciate and experiment with face biometrics at the mathematical level that freshmen are comfortable with. This was a very big challenge that the senior clinic student surmounted. A publication [3] has resulted from the work.
3. During the spring semester of the senior year, the student was ready to begin biometrics research. The background and knowledge gained in the previous semester easily led to the configuration of a speech biometrics system in MATLAB. The student was able to transition from one biometric modality to another (face recognition to speaker recognition) with great ease. The focus of the student's research is to find novel methods to augment performance for a system trained on clean speech and tested on speech corrupted by different sources of additive noise (mismatched training and testing conditions).
4. The student has smoothly transitioned to graduate school at Rowan and is continuing the speaker recognition project. A Gaussian Mixture model based system has been configured. Since additive noise at a global signal-to-noise ratio (SNR) corrupts the speech signal non-uniformly over different smaller duration temporal regions, the goal is to find which temporal regions are relatively clean and thereby more useful for speaker recognition. These useful temporal regions are known as the regions of 'usable speech' [4]. The student is currently testing a novel algorithm to blindly detect 'usable speech' and is expected to graduate in one year's time. Research publications will result.

Reflective Piece

The reflective piece was obtained from two graduate students that have transitioned from the clinic work and three international graduate students were collected. They are presented in “*italics*” below.

Rowan graduate students

Graduate student A

“The jr./sr. engineering clinics at Rowan University prepared me for graduate school by providing a comprehensive approach to learning. The clinics bridge the material presented in a lecture to the application of the material, as well as, furthered my knowledge with the development of new techniques and approaches. While studying as an undergraduate I had taken classes in civil engineering materials, transportation engineering and pavement design, which provided me a working knowledge to preparing me for career. The clinics expanded my understanding of the material and introduced me to new material like reclaimed asphalt pavement, warm mix asphalt, modified binders, which typically aren’t discussed in detail in class. Furthermore the clinics provided an opportunity to hone my soft skills by writing project reports and presenting our research and designs to our clients and other professors. By performing hands on testing and analysis as an undergraduate I gained a deeper understanding of testing results which has helped me extensively in my research as a graduate student.”

Graduate student B

“It was because of Junior/Senior Clinic at Rowan university that I wanted to go to graduate school. Through various other classes at Rowan University, I knew what engineering graduate school entailed. The way it was described it sounded like a lot of reading papers, writing paper and it basically revolved around papers. Through that description I was not thinking about graduate school. Once I got into my junior year, all of the clinic projects were presented by the professors running the projects. Through an engineer’s-without borders club organization, I had already chosen a clinic project but hearing about all the other research projects made me consider possibly trying for other clinic projects to work on. After attending two sets of end of the semester clinic presentations, I decided I wanted to do some research over the summer with Dr. Mehta, as his classes sparked my interest. That summer I worked on a few different projects for Dr. Mehta doing various tasks of surveying to statistical modeling. The work I was doing kept me interested and wanting to do more. Over the summer I worked with some other undergraduate students along with some graduate students at Rowan University. During my senior year I continued on a Reclaimed Asphalt Pavement project that I had worked on during the summer. Through my senior clinic I was able to continue the research I enjoyed. After working with different graduate students I realized I enjoyed research. I came to realize that, though papers are an important aspect of graduate school, without the research and testing

being completed the paper aspect of graduate school is limited. After this realization I started to think about graduate school and decided to continue doing different pavement research projects for Dr. Mehta.”

International Graduate students

International Graduate Student C

“As a graduate student at Rowan University, I worked on the research project funded by the Federal Aviation Administration. The quality and graduate level of education was totally different than at back home in terms of coursework, lecturers, classroom experience and the practical training. The clinic programs helped me receive direct assistance from the undergraduates who worked on my research. Working with the undergraduates helped me overcome the barrier in learning styles in the US and my home country. Apart from the help I received on my research projects, I also picked some managerial skills, communication skills and got acquainted with the social life in the US. The undergraduate students also benefitted from the clinic projects as they became familiar with what the industry has to offer for them after graduation and gave them a direction about what aspect of engineering they would like to be involved in. While I now work for a major engineering firm, I also realize that working with the undergraduates benefitted me in the long run as well as I also became familiar with the work culture and work ethics expected in the US earlier in my college life.”

International Graduate Student D

"It's a very good practice to include clinic projects in the master's program. For an international student, it takes time to get accustomed with the curriculum pattern and education system like having different class and holiday schedules, exam pattern, grading system, using metric unit system, etc. The clinic students helped me understand and adapt to the new system quickly. The clinic projects gave me a chance to work, interact and exchange ideas with junior / senior students. The clinic sessions were more like group discussions and problem solving meetings where everyone learnt something new from each other. The students inspired me with their hard work, efficiency, computer skills and writing skills. Most importantly, it helped me boost my confidence and my communication skills. The clinic group activities were not just limited to running computer programs, writing papers and giving presentations but also included entertainment, celebrations and festivities which served as much needed de-stressors. Being an international student, I needed something like this to open up to the new environment. What I also learnt from this exercise is the importance of resource management and proper distribution of work. It also gave me a perfect opportunity to test my leadership and management skills. This experience has helped me do well at my workplace where I work in a team environment."

International Graduate Student E

“When I begin my stint at the Rowan University as a graduate student, I was introduced to the clinic students of which few even became my colleagues for research. Being an International student, my first challenge was to bridge communication gap due to different cultures, ethnicity and different education systems. I became a part of different work cultures while engaging in lab activities. I earned the hands on experience of team work and also became more confident while working in team. Frequent Interaction, discussions with clinic students made me focus more on my work and studies. Practical aspect of the engineering is one of the biggest things I learned from working along with clinic students. In a way, it improved my personality in all respect. I give credit to the clinic students for making coursework simpler for me in a foreign country.”

Discussion

Rowan University Graduate Students

The reflective piece from two Rowan graduate students who had worked on the clinics as undergraduate students appeared to indicate that the clinics not only helped them get proficient with the technical aspects of the research projects but also sparked the curiosity and interest to pursue graduate studies. This success story is being repeated among students across the college of engineering as more faculty members are engaged in funded research.

International Graduate Students

The reflective piece from three international graduate students indicated there were three benefits:

- 1) it helped them get assimilated in the culture more seamlessly, making the graduate experience more enjoyable
- 2) the interaction with clinic students helped them gain confidence because they had to lead a team of 3-4 students.
- 3) Improve communication skills helped them in getting a job and also continue to help them in their job.

Substitution for Clinic Experience

Several universities with a strong undergraduate education focus may not have a clinic experience for undergraduate students within their curriculum. However, it might be worth introducing a similar type of an experiential based course within the curriculum to ensure that undergraduate students get hands-on research experience as part of their degree. Such an experience would not only serve as a catalyst for students to pursue advanced degrees, but also an opportunity for faculty members to conduct research. The Electrical Engineering program [5] at the University of Central Florida utilized the machine learning research program funded by the National Science Foundation to involve undergraduate students, who went on to pursue graduate

school. Another example of the desire of students to pursue graduate studies due to an undergraduate research experience in Industrial Engineering is discussed in [6].

Conclusions

The conclusions based on the study presented here show the following:

- 1) The clinics continue to be an excellent vehicle to transition to graduate school not only at Rowan University but also other top engineering schools in the nation. Clinics also serve as a catalyst to get them excited about graduate school and sparks their curiosity to learn more.
- 2) The clinic experience is very valuable for the international graduate students in improving their communication skills, providing experience in leadership and management skills, and hence developing their overall confidence.
- 3) The undergraduate research experience, if provided within the curriculum, could serve as an excellent vehicle to promote research in institutions with strong undergraduate education focus.

Acknowledgement

This work was supported by:

- a) The U.S. Air Force Research Laboratory, Rome, NY, under contract FA8750-10-C-0249,
- b) The National Science Foundation through the Grant DUE-1122296,
- c) The New Jersey Department of Transportation,
- d) The Federal Aviation Administration, and
- e) Delaware River Port Authority.

References

1. P. Shuster, and C. Birdsong. Research in the Undergraduate Environment, *Proceedings of the ASEE Annual Conference*, 2006.
2. P. Jansson, R. P. Ramachandran, J. L. Schmalzel and S. A. Mandayam, "Creating an Agile ECE Learning Environment Through Engineering Clinics", *IEEE Transactions on Education*, Vol. 53, No. 3, pp. 455-462, August 2010.
3. S. Davis, M. Frankle, R. P. Ramachandran, K. D. Dahm and R. Polikar, "A Freshman Level Module in Biometric Systems", accepted in *IEEE Int. Symp. on Circuits and Systems*, Beijing, China, May 19-23, 2013.
4. B. Y. Smolenski and R. P. Ramachandran, "Usable Speech Processing: A Filterless Approach in the Presence of Interference", *IEEE Circuits and Systems Magazine, Special Issue on Speaker and Language Recognition*, Vol. 11, No. 2, pp. 8-22, June 2011.
5. M. Georgiopoulos, R. DeMara, A. Gonzalez, A. Wu, M. Mollaghasemi, E. Gelenbe, M. Kysilka, J. Secretan, C. Sharma, and A. Alnsour, "Sustainable Model for Integrating Current Topics in Machine Learning Research Into the Undergraduate Curriculum", *IEEE Transactions On Education*, Vol. 52, No. 4, November 2009.

6. C. A. Yauch, "The Impact of Undergraduate Research Experiences on Graduate School Pursuit by Industrial Engineers" [*IEEE Frontiers in Education Conference*, 2007.](#)