A Conceptual Inter-Graduate Framework to Prepare the Future Faculty

Sridhar Ramachandran, Kumar Yelamarthi, Sanjay Boddhu, and P. Ruby Mawasha

College of Engineering and Computer Science
Wright State University
Dayton, OH 45435
Email: {ramachandran.4, yelamarthi.2, boddhu.2, ruby.mawasha}@wright.edu

Abstract
Engineering is a rapidly evolving field that embraces novel ideas. The rapid advancement in technology is currently offering possibilities for tomorrow’s engineers, and is facilitating the successful conception of designs and models that span across multiple disciplines. This in turn presents new challenges to the future faculty who will be required to vary the degree and type of attention, help, advice, information, and encouragement that he/she provides to the future engineers. Meeting the challenge is in part possible with the efficient integration of an inter-graduate framework that equips the future faculty with fact-based mentoring models.

The success of the future engineers is profoundly dependent on the potential and talented mentors. The conceptual framework presented in this paper is a proactive effort to prepare the future faculty and address the technological challenges and opportunities of the future through better preparing the future engineers. The framework presented in this paper is based on the following premises, (i) the efficiency of the future faculty in mentoring undergraduate students can be improved significantly with the better understanding of the student learning process; (ii) the future engineering designs will necessitate inter-disciplinary collaboration; (iii) engineering research should not be limited to graduate students and faculty.

The framework presented in this paper will aid in the disbursement of efficient techniques to current student mentors and better prepare them as future faculty. The added advantages with this framework are (a) the conception of a platform for research in undergraduate education; (b) a model that can be easily implemented to evolve dynamically or at least linearly over time and improve the effectiveness of future engineers; (c) improved networking and partnerships between academia and the industry.

Introduction
The Engineer of 2020 report\(^1\) proclaims the need for cross-trained engineering faculty who can assume multidisciplinary roles in engineering education. Likewise, the ASEE’s Engineering Education for A Changing World\(^2\) has envisioned the need to prepare the current students for a broad range of future careers and lifelong learning. Similarly, the National Research Council’s Board of Engineering Education\(^3\) has strongly recommended reforming the current curriculum to incorporate interdisciplinary awareness. The underlying recurring theme is that the traditional undergraduate and graduate student mentoring models ferment for reform.
Previous research has reported that mentoring has significantly benefited the communication, problem-solving and critical thinking skills of the undergraduate student group\(^5\). During the senior year, traditionally students choose a faculty advisor and obtain the project to work towards their capstone project. With the project and fellow team members (from the same discipline) identified, students undergo some courses required and work towards completion of the project. This approach shown in Figure 1 (a) has several drawbacks such as, limiting the acquired skill set through working only on one discipline, lack of opportunities to work with others (from a different discipline) on issues of common interest, absence of understanding the range of research methods that can be used and their strengths and limitations, and also a clear but flexible vision of how they are to be integrated. Figure 1 (b) shows the basic traditional mentoring model for a graduate student. This approach also has several shortcomings such as, insufficient exposure to multidisciplinary projects, absence of student mentoring opportunities and no real student project management experience.

The present need is to learn and adapt new approaches to mentoring, teaching and learning which in turn will facilitate effective professional development for both new and experienced faculties\(^4\). Understanding of the student learning process can be improved with the right information, appropriate guidance and directed feedback from faculty mentors and fellow graduate student mentors alike. Therefore there is a genuine necessity to bridge the gap between the two models shown in Figure 1 to mutually enrich the undergraduate student experience and the preparation of the future faculty (current graduate students).

One effective way to meet this growing challenge is to educate the current graduate students (the future faculty) with undergraduate mentoring opportunities. In this paper we propose a systematic pedagogic model to complement the traditional mentoring models while encouraging the future faculty to prepare early to meet the ulterior challenges. First, an optimal time period in the graduate student’s curriculum for participation in the model is presented, followed the details of the activities encouraged/enriched by the model. Finally the analysis and benefits of the model are presented.

Figure 1: Traditional mentoring models

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Inter-Graduate Mentoring Framework

Optimal Time for Graduate Student Participation

Our model assumes that the graduate student educational cycle involves three major stages/phases as shown in Figure 2. The first phase involves completing the required coursework (CW) and qualifying as a Ph.D. candidate. The second phase involves identifying the research topic and conducting preliminary research to successfully defend the research proposal (PR). The final stage involves conducting scholarly research towards defending the dissertation work and eventual graduation (DS). In Figure 2, the shaded portions identify the ideal timeframe for graduate students to undertake mentoring roles and be exposed to interdisciplinary project teams.

Demands for Enriched Mentoring

It has been previously reported that mentors encouraging undergraduate research have played a positive role in graduate school recruitment and retention. Also, mentoring roles provide means of cultivating and encouraging talent to the mentors while serving as resources to motivate undergraduate students. Through participation in the proposed model, the future faculty (current graduate students) will gain skills in effective mentoring, and insights in areas of recruitment and retention to better tune the courses they will teach further in their career.
Figure 3(a) shows the combined mentoring model. By tradition, the faculty has to mentor the undergraduate teams and the graduate student researchers. With the rapidly evolving engineering curriculum, the mentoring responsibilities of faculty mentors are rapidly increasing. With new emerging unpredictable and unknown research problems, the future will demand a very interactive faculty and graduate student interaction as shown in Figure 3(b). The graduate student needs to possess skills that will make him/her globally competitive. They need to appreciate the power and importance of team-building at an early stage in their engineering profession. This demands that graduate students be exposed to project management as shown in Figure 3(c). With single discipline research destined to encountering a bottle-neck in the future, the future faculty will need a skill set of more than one discipline to make breakthroughs. This demands that student researchers learn about one another’s disciplines as shown in Figure 3(d).

An ability to function well in a multidisciplinary team has become an expectation of modern industry and a major goal for engineering students. Moreover, it has been previously reported that mentors encouraging undergraduate research have played a positive role in graduate school recruitment and retention. Research studies have shown that mentors who have supervised undergraduate teams have gained cognitive and personal skills. These qualities are essential for the growth of the graduate student upon recruitment as a faculty.

With the above mentioned objectives in consideration, our model is framed to encourage/enrich the necessary mentoring activities to be adopted by a graduate student. Figure 4 shows our inter-graduate mentoring framework as it will be evolving over time (from left to right). Each hierarchical mentoring block shows the enhanced interaction between the faculty, the graduate students and the undergraduate inter-disciplinary team members. Each level in the hierarchy benefits for internetworking communication links. With time, the model dynamically evolves to strengthen the weak communication bonds (when the current graduate mentor graduates up the hierarchy- the diagonal arrow from Graduate Mentors to Future Faculty Mentors).

![Inter-Graduate mentoring framework](image)
Discussion
On the inculcation of the model as a curriculum/non-curriculum option for the graduate students, the model will evolve and mature in time not less than the period of an ideal graduate study. An immediate benefit to implementing this model is the additional mentoring available to undergraduate student teams, real-time mentoring feedback to graduate students, improved graduate-graduate and graduate-undergraduate interaction and work load sharing to the faculty mentor. Though an informal environment similar to the one presented in this paper may exist in some technical universities a need for a formal framework was the inspiration for this model.

Data Collection
Two questionnaires have been prepared; one for undergraduate, and the other for graduate student participants as shown in appendix-A. The model is in full implementation now with all levels clearly defined and represented. The increasing attendance at the bimonthly meetings of the participating graduate students shows promise of the model’s growing popularity. At this time the survey data for the model is not available for inclusion.

Benefits
The framework presented in this paper will aid in the disbursement of efficient techniques to current student mentors and better prepare them as future faculty. The added advantages with this framework are (a) the conception of a platform for research in undergraduate education; (b) a model that can be easily implemented to evolve dynamically or at least linearly over time and improve the effectiveness of future engineers; (c) improved networking and partnerships between academia and the industry.

The framework presented in this paper will also aid in disbursement of efficient techniques to the current student mentors and prepare them to work in industry. The added advantages with this framework are (a) have a clear understanding of a product design cycle; (b) become an effective team player; (c) enhance leadership qualities to become a project leader; (d) improved networking with the participating industries; (e) nurturing mentorship skills; (f) entrepreneurship skills; (g) tech transfer.

Future Goals
The authors are currently working towards recommending the model for inclusion as a formal framework for student mentoring at their home institution. A methodology to recognize the efforts of the participating graduate mentors will aid in encouraging more participation. A qualitative method of research in this area involving interviews with participating graduate mentors observation of the mentoring process and focus groups is being developed to further this model. This work is a subset of a long term study looking at the effects of mentoring on undergraduate student retention and graduate student recruitment.
References
Appendix-A

Survey for Undergraduate Student Participants

1. Write effectively
   1 (Low)  2  3  4  5 (High)

2. Speak effectively
   1 (Low)  2  3  4  5 (High)

3. Listen effectively
   1 (Low)  2  3  4  5 (High)

4. Approach problems in a creative manner
   1 (Low)  2  3  4  5 (High)

5. Better understand myself
   1 (Low)  2  3  4  5 (High)

6. Solve problems independently
   1 (Low)  2  3  4  5 (High)

7. Understand ethical implications
   1 (Low)  2  3  4  5 (High)

8. Cope with conflict
   1 (Low)  2  3  4  5 (High)

9. Perform independent research
   1 (Low)  2  3  4  5 (High)

10. Understand math concepts
    1 (Low)  2  3  4  5 (High)

11. Appreciate artistic & creative experiences
    1 (Low)  2  3  4  5 (High)

12. Know literature of merit in field
    1 (Low)  2  3  4  5 (High)

13. Understand cultural differences
    1 (Low)  2  3  4  5 (High)

14. Strengthen interpersonal relationship skills
    1 (Low)  2  3  4  5 (High)

15. Maintain openness to new ideas
16. Possess clear career goals
   1 (Low)  2  3  4  5 (High)

17. Work as part of a team
   1 (Low)  2  3  4  5 (High)

18. Synthesize & use information from diverse sources
   1 (Low)  2  3  4  5 (High)

19. Develop intellectual curiosity
   1 (Low)  2  3  4  5 (High)

20. This program contributed towards learning experience.
   1 (Low)  2  3  4  5 (High)

21. This program increased my interest in engineering.
   1 (Low)  2  3  4  5 (High)

22. This program increased my ability to design and conduct experiments, as well as to analyze and interpret data.
   1 (Low)  2  3  4  5 (High)

23. This program increased my ability to design a system, component, or process to meet desired needs.
   1 (Low)  2  3  4  5 (High)

24. Through this program, I am able to understand the necessity and importance of science and engineering in my day-to-day life.
   1 (Low)  2  3  4  5 (High)

25. What is your rate of rapport with your mentors in this program?
   1 (Low)  2  3  4  5 (High)

26. Did you participate in any academic seminars and workshops during this program?
   Yes   No

27. During this program, did you use any of the campus facilities for the first time?
   Yes   No

28. Though this program, did you come to know what needs to be done in order to get into graduate school?
   Yes   No

29. Did the monetary support provided by this program help you in any means?
   Yes   No
# Survey for Graduate Student Participants

1. Approach problems in a creative manner
   1 (Low) 2 3 4 5 (High)

2. Better understand myself
   1 (Low) 2 3 4 5 (High)

3. Acquire info on my own
   1 (Low) 2 3 4 5 (High)

4. Solve problems independently
   1 (Low) 2 3 4 5 (High)

5. Act as a leader
   1 (Low) 2 3 4 5 (High)

6. Understand ethical implications
   1 (Low) 2 3 4 5 (High)

7. Cope with conflict
   1 (Low) 2 3 4 5 (High)

8. Understand scientific findings
   1 (Low) 2 3 4 5 (High)

9. Appreciate artistic & creative experiences
   1 (Low) 2 3 4 5 (High)

10. Know literature or merit in field
    1 (Low) 2 3 4 5 (High)

11. Analyze literature critically
    1 (Low) 2 3 4 5 (High)

12. Strengthen interpersonal relationship skills
    1 (Low) 2 3 4 5 (High)

13. Maintain openness to new ideas
    1 (Low) 2 3 4 5 (High)

14. Possess clear career goals
    1 (Low) 2 3 4 5 (High)

15. Work as part of a team
    1 (Low) 2 3 4 5 (High)
16. Think logically about complex material
   1 (Low) 2 3 4 5 (High)

17. Synthesize & use information from diverse sources
   1 (Low) 2 3 4 5 (High)

18. Develop intellectual curiosity
   1 (Low) 2 3 4 5 (High)

19. This program contributed towards learning experience.
   1 (Low) 2 3 4 5 (High)

20. This program increased my ability to design and conduct experiments, as well as to analyze
    and interpret data.
   1 (Low) 2 3 4 5 (High)

21. What is your rate of rapport with your mentors in this program?
    1 (Low) 2 3 4 5 (High)

22. Did you participate in any academic seminars and workshops during this program?
    Yes  No

23. Did the monetary support provided by this program help you in any means?
    Yes  No