Student Learning and Development in the Context of Dissertation Research

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Abstract

At the University of Kansas, the Bioengineering Graduate Program has undertaken a process to develop objectives, outcomes, and measures of student learning and development in the dissertation research of PhD students. Two measures of student learning, the graduate learner outcomes dissertation rubric and peer-reviewed publication of graduates, are presented in this paper. It was found that assessing peer-reviewed publications, particularly in relationship to the year of graduation, yields information on the volume and success of a student's research productivity. It may, however, be influenced by other factors such as laboratory size. Future work will include examination of early (entrance) and intermediate measures.

Keywords

Graduate, Research, Dissertation

Introduction

The Bioengineering Graduate Program at the University of Kansas was started in 2007 and offers an M.S. and PhD. in Bioengineering. Additionally, it has an accelerated BS in Engineering (Mechanical, Electrical, Chemical, Aerospace, or Civil) to MS in Bioengineering program for high achieving undergraduates at the University of Kansas. As part of the Higher Learning Commission (HLC) accreditation of the university, graduate programs are evaluated along with undergraduate programs. In preparation for this accreditation review, the Bioengineering graduate program undertook to develop program objectives and outcomes to examine student learning at the graduate level. At the graduate level, thesis and dissertation research is a significant component of the educational process. As such, this paper will focus on developing objectives and outcomes related to research education and developing measures of student learning in research education, particularly at the doctoral level.

While undergraduate programs in engineering are accredited via the Accreditation Board for Engineering and Technology (ABET), ABET does not accredit doctoral degree programs. The HLC does accreditation of universities that includes all degree programs within that university. The HLC accreditation criteria for programs within a university include[1]:

3.A.2 The institution articulates and differentiates learning goals for its undergraduate, graduate, post-baccalaureate, post-graduate, and certificate programs.

3.B. The institution demonstrates that the exercise of intellectual inquiry and the acquisition, application, and integration of broad learning and skills are integral to its educational programs.

These criteria are quite general, leaving room for interpretation. It was the goal of the Bioengineering graduate program to develop objectives, outcomes, and measures that can also be useful in improving the quality of the graduate program.

Learning Objectives and Outcomes in Research

The objectives of PhD research education are centered on developing an independent scholar who is capable of performing research at a faculty level. Faculty advisors and dissertation committee members look to see that the student is capable of being a colleague in the research enterprise and will often express such performance as "I know it when I see it". As Mullins and Kiley state[2]:

"Experienced examiners make judgements about the quality and quantity of students' work based on their own extensive experience or mastery of the area. These examiners 'know' what constitutes a passable or outstanding thesis."

This expertise can be field specific and standardized measures are not well documented. Learning objectives include students having a deep knowledge of their research area and the published literature, being able to evaluate scientific literature broadly across their field of expertise, having the ability to do independent research, and having the ability to communicate that research successfully through publication. Other objectives include having technical skills in important techniques of their field, being able to supervise the research of others, and being able to formulate novel research questions that might serve the basis of grant proposals. Some will express a volume of work such as three peer reviewed journal publications as an objective.

In Bioengineering, our goal was to select outcomes that embody these objectives. These outcomes were:

Graduates in PhD Bioengineering program will be able to:

1. *Read, comprehend, process and communicate (written and orally) scientific literature in the bioengineering field.*

2. *Develop and execute scientific research aims including formulating hypotheses and developing methods to test these hypotheses.*

3. *Demonstrate a depth of knowledge of fundamental topics in the student's track of study (biomechanics and neural engineering, biomaterials and tissue engineering, bioimaging, bioinformatics, biomolecular, or biomedical product design and development).*

4. *Complete original, publishable and impactful research in a bioengineering area within a reasonable time frame.*

Available Metrics

Much of these outcomes are evaluated by the qualifying exam, the comprehensive exam, the dissertation, and the oral defense. The Bioengineering PhD program at the University of Kansas the qualifying exam requires a student to examine a peer-reviewed publication and present that

research and its limitations both written and orally. The comprehensive exam requires the student to prepare their research plan as a proposal (following the model of an NIH grant proposal) and defend that proposal in an oral presentation to their dissertation committee. Additional stages of assessment are during entrance to the program (measuring preparation), at regular (annual) student progress reviews, and after graduation from the program. Measures that are assessed through this process include:

Entrance
        – Assessing preparation for graduate research
                Undergraduate GPA and Major
                GRE scores
Qualifying exam completion (PhD)
        – Assessing preparation for graduate research and outcome #1
                Core coursework fulfillment and classroom performance
                Written & oral exam performance
Comprehensive exam completion (PhD)
        – Assessing outcomes #2 and #3
                Comprehensive Exam Rubric (in preliminary stages of implementation)
Doctoral defense and dissertation (PhD)
        – Assessing all outcomes
                Graduate Learner Outcomes Dissertation Rubric
Plan of study and annual progress review
        – Assessing outcome #4
                Time to completion of the PhD
                Publication Record
                Awards
Alumni follow-up
        – Assessing Outcomes #4
                Job Placement
                Publication Record
                Alumni Entrepreneurship Activities

Graduate Learner Outcomes Dissertation Rubric

To develop a metric that could assess dissertations across different research areas, we focused on five topics: 1. Knowledge of the Literature/Field/Methods and Techniques, 2. Methodology and Interpretation of Results, 3. Original Thoughts/Ideas/Contributions, 4. Quality of Writing and Presentation, and 5. Volume of Work and Publications. The dissertation committee is asked to rate the dissertation collectively based on these topics and four levels of competence: Honors, Outstanding, Acceptable and Inadequate. The committee is given the following instruction on the grading of each topic:

  Knowledge of the Literature/Field/Methods and Techniques

  An honors dissertation level candidate would have a strong knowledge of the literature, the breadth of the field, and the applicable techniques related to their research. This

should be demonstrated by a comprehensive literature review, integration of the literature with the interpretation of dissertation research, and the ability to address questions through the use of literature sources. One would expect an honors level candidate to be able to educate their advisor and committee members on literature immediate to their research. An outstanding candidate has demonstrated a better than acceptable level of knowledge but has not achieved the mastery of an honors candidate. An acceptable dissertation level candidate will have a solid knowledge of literature and applicable techniques that will be demonstrated in the literature review and in the discussion of research results as they relate to the literature. They should be able to use the literature in fielding of questions during the defense but may not always be able to do so. Such a student may not know all literature that might be applicable to the research project but should have sufficient knowledge to adequately cover the field. The candidate should address the literature in discussions of results but may not have strong literature based arguments for their interpretation. An inadequate candidate has significant gaps in their knowledge of the literature in the field or the applicable methods and techniques that exist related to his/her research. The discussion and interpretation of research is devoid of appropriate integration with the literature. He or she may not be able to address questions during the defense based on literature sources.

Methodology and Interpretation of Results

An honors dissertation level candidate should have a clear, thorough and easily reproducible description of the methodology used and results obtained in the research. The methods used should have been selected carefully from available methods and be well justified. Results should have appropriate statistical or other numerical approaches in their analysis. The candidate should have a comprehensive knowledge of the methods used, their strengths and limitations, and alternative methods. The interpretation of the results should be thorough and address multiple possible explanations of the results. Strengths and limitations of the findings should be clearly stated and complete. Such a candidate clearly addresses how the findings can be applied to the bigger picture of clinical or scientific concern and what future work should be done. An acceptable dissertation level candidate will have a clear and complete description of methods and results obtained. The results should have appropriate statistical or other numerical approaches in their analysis. Strength and limitations of the findings should be addressed adequately. Such a candidate will address how their findings apply to the bigger picture. An inadequate candidate may have a poorly described methods description, incomplete presentation of the results or inappropriate statistical or numerical analysis of the findings. Strength and limitations may be not be addressed or may be addressed inadequately. Such a candidate may not be able to appropriately address what their findings mean to the bigger picture.

Original Thought/Ideas/Contributions

An honors dissertation level candidate should have developed significant portion of the methodology in the dissertation without much direction from the advisor. Many ideas and concepts in the dissertation should be the candidate's own, resulting from their extensive understanding of the literature and their own research findings. Such a candidate may have started under the direct guidance of the advisor, but has moved to the role of independent researcher. This can be evidenced by a dissertation that is a significant departure from the advisor's writings, grants, and other work. It may also be evidenced by a dissertation defense discussion where the candidate is able to explain how they moved the research in new and original directions. An acceptable dissertation level candidate will have developed some original ideas and contributions within a dissertation project. However, their research is mostly based in the advisor's research direction and proposals. An inadequate candidate has little understanding of the research beyond what they have learned from their advisor. This is demonstrated in the discussion by a lack of ability to address simple research questions and a lack of discussion in the dissertation beyond the basic findings.

Quality of Writing and Presentation

The dissertation of an honors level candidate should be relatively free of editing and formatting issues at the time of the defense. The writing should be clear and succinct with a format that is easy to follow. The prose should be reasonably elegant with variations in sentence structure and language that make the text easier to read while maintaining appropriate scientific writing standards for technical communication. The dissertation defense presentation should be well-organized and thorough with clear, easy to read visuals. The candidate should present in a clear, loud, and animated voice that maintains audience interest. An acceptable dissertation level candidate will have a dissertation that needs some editing or formatting correction at the time of the defense but does not have significant editing issues. The writing may need some work to be clear, succinct and well-formatted but this work should be easy to accomplish prior to submission. The defense presentation should be organized and have adequate coverage of the research. Visuals should be readable, if not easy to read. An inadequate candidate has a dissertation with major editing and formatting issues that make it difficult to read. The defense presentation may be poorly organized with difficult to follow visual aids.

Volume of Work and Publications

An honors dissertation level candidate should have research work that can lead to a number of peer-reviewed journal publications (three or more). Ideally, several of these are already submitted and some are even in press. An acceptable dissertation level candidate will have research work that can lead to at least one and preferably 2 or more peer-reviewed journal publications. An inadequate candidate has little potential for publication of the dissertation work in a peer-reviewed journal.

As the program is young and the rubric was only recently implemented, only ten PhD graduates have so far been evaluated with this rubric. Each category is rated by the student's dissertation committee as 1 for inadequate, 2 for acceptable, 3 for excellent, and 4 for outstanding. It is still premature to gather meaningful information from these results with such a small sample size. However, no students were found to perform below adequate in any category and most were excellent or above in many categories, indicating that defending students are well equipped. However, this assessment is limited to those that have completed their dissertation and does not take into account the timeliness of completion. Additionally, it will exclude those that never complete their dissertation due to a number of factors that could include inadequate preparation, unsuccessful supervision and laboratory training, or other factors. If a supervisor views a student as prepared to defend their dissertation, it is likely they have already been determined to be at least acceptable.

Publication Record

Another measure of outcome #4 is the volume of publication produced by PhD graduates. Publication is a measure that has been assessed by others, although typically is assessed relative to number of faculty rather than to PhD graduates[3]. To evaluate publication in peer-reviewed journals, an analysis of publications listed in the PubMed database was assessed for the 14 PhD graduates as of Spring 2014 (Figure 1). Pubmed was used because most prominent Bioengineering journals are included within this database. This database also has a number of quality controls that would exclude publication such as conference proceedings. It has been recognized that some journal publications (such as one identified for a student in an IEEE journal) will not appear in this search. For these graduates, the average number of publication coauthored with their research advisor and appearing in Pubmed is 6.2 publications. Some student may be over counted due to post-doctoral research with the same advisor. Additionally some may have a larger number of publications if they did their MS research in the same laboratory.

Of particular interest to the faculty was the timeline of publication. To examine this, the publication year of each paper was compared to the student's graduation year (Figure 2). By examining this data it was determined that publication should be examined at least two years post graduation in order to have a complete picture of publications associated with dissertation research. Additionally it was found that only a few students manage to publish more than a year before graduation. This suggests that the program should focus on encouraging early publication rather than waiting until the dissertation is completed.

This analysis includes all papers that involve the student and their research advisor. This can include papers in which the student is first author as well as papers in which the student is a middle author. These later papers can be the result of being involved in papers that are a part of another student's major work in a collaborative laboratory setting. Additionally, some of these papers are review papers. Some advisors have encouraged their students to collaborate with them on a review paper at an early stage of their career to help them develop a strong knowledge of the literature. Students from large laboratories were identified to have a larger number of publications (8) than those from labs with fewer researchers (3.8). Future analysis could include examining the number of first author papers by each student, which may give a more balanced view of different laboratory sizes.
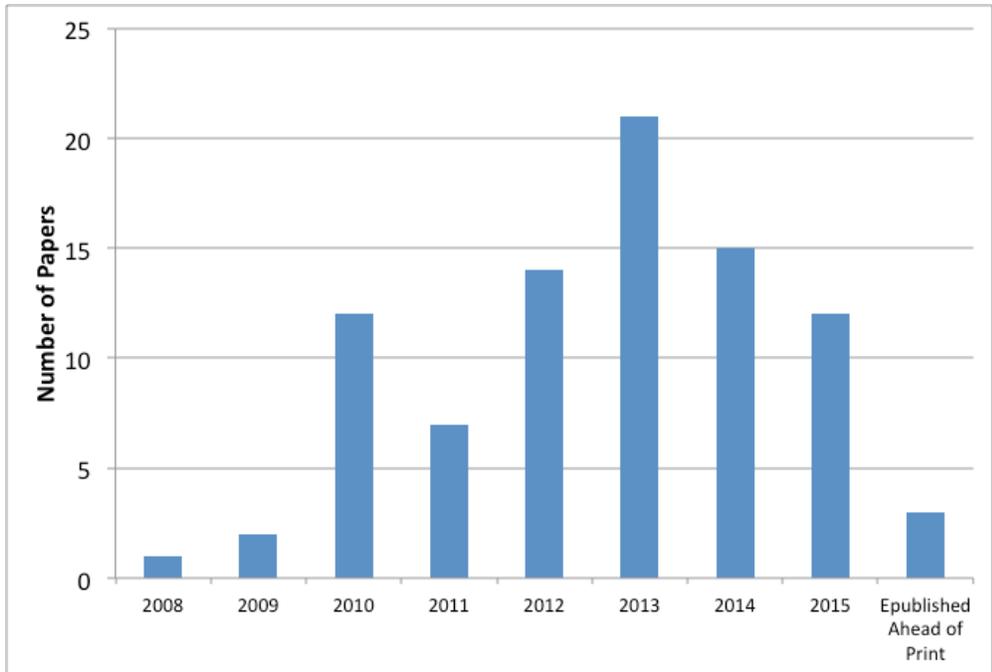
Figure 1. Publication of PhD students by year. Those published electronically and listed in Pubmed but not yet in print are included. The program began in 2007 and the first PhD student graduated in the summer of 2010.
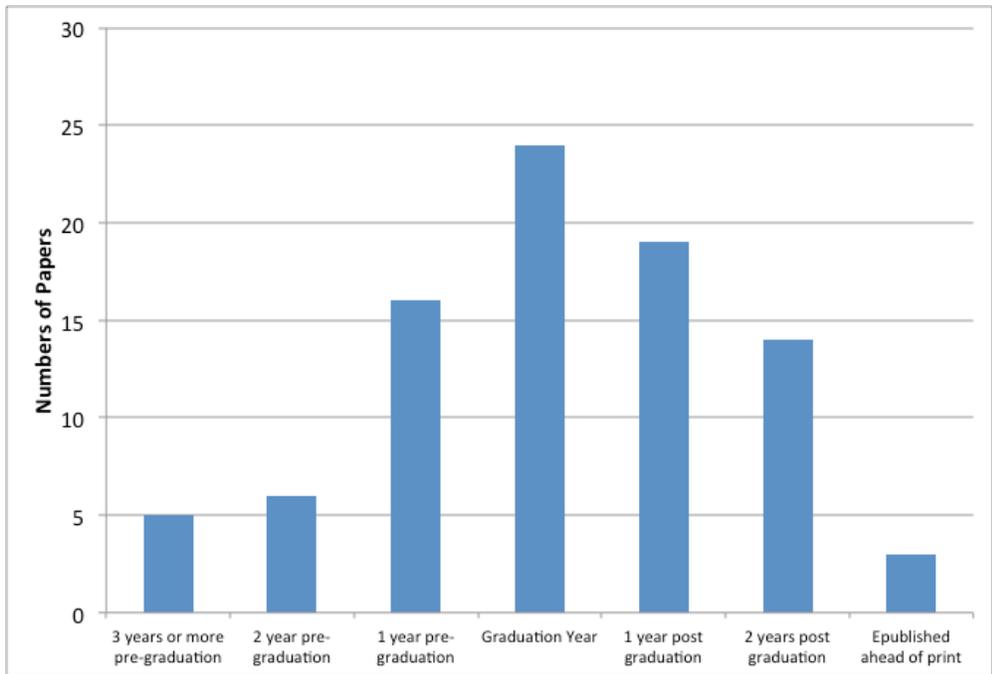

Figure 2. Publication of PhD students relative to their year of graduation. The majority of publications were published between the year prior to graduation and two years post graduation.

Other Measures

In addition to the dissertation rubric and the publication record of graduates, other measures that have been of particular interest have been the job placement and entrepreneurship activities of graduates and measures of intermediate performance such as a rubric for the examination of comprehensive exams. Alumni placement can be challenging to follow as many PhD graduates do not join alumni organizations. As such, the program has used Linked In as a way to maintain contact and follow the careers of graduates. Of particular interest has been the number of students who founded their own companies (currently seven MS and PhD graduates). In the future, we may also seek to track the numbers of patents of students as another indicator of future entrepreneurial potential.

Intermediate measures are still in development. These include the comprehensive rubric that has been developed but has yet to be deployed. Finally, it would be interesting to examine the relationship between early (entrance) measures, intermediate measures, and these final dissertation and publication measures.

Conclusion

In this paper, the outcomes and measures of a doctoral program in Bioengineering have been presented. In particular, two measures, the graduate learner outcomes dissertation rubric and the publication record of PhD rubrics were examined. These two measures present a picture of the quality of student learning that occurs in PhD research education. These measures are both limited, missing those students who do not complete their dissertation and as such only demonstrate the program's success. The publication record was found to be more informative as it demonstrates the ability to differentiate different research experiences (such as size of laboratory). Future directions with this data include examining more carefully the timing of publication to identify factors that lead to early publication. In addition, these data should be compared to time to graduation data.

Intermediate and early (entrance) measures should also be examined further. These measures could help to identify better predictors of student preparedness at entrance, quality of research supervision, and methods to speed growth in research aptitude. These measures may also be important in assessing factors that lead to a lack of completion of the dissertation. Finally, these measures are also being developed to examine MS thesis student learning.

References

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