AC 2011-1908: THE RESEARCH PROPOSITION AND PROFESSIONAL DEVELOPMENT: UPDATE ON FIRST YEAR GRADUATE STUDENT PREPARATION

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The Research Proposition and Professional Development: Update on First Year Graduate Student Preparation

Twenty years ago, our department initiated an independent research proposition course for all first year PhD candidates. Student performance in this spring semester three unit course was treated as a graduate qualifier exam, and both students and faculty have been supportive of this requirement, as summarized earlier[1].

Over the last decade, our first year approach to research education has broadened. Peter Kilpatrick added a one unit fall course, Introduction to Research, a professional development course including research ethics, presentations, and publications. While these two courses were satisfying as stand-alone efforts, recent faculty and graduate student sentiment pushed for an earlier engagement of student with research advisor, PhD committee, and research itself.

In response, we have developed a yet broader first year experience encompassing a pair of two unit courses, one each in fall and spring. In the first, professional development topics are followed by creation of an independent, ten page research proposal. The second, spring semester effort requires the student, in consultation with her new advisor, to develop a NSF length proposal for the prospective PhD effort, and present it to her nascent PhD committee and course instructor. Additionally, earlier engagement with the PhD committee is now achieved through a January, second year oral report to the PhD committee. The customary university Preliminary Exam occurs at the beginning of year three, and includes both a document (progress and plans) and an oral presentation.

In summary, we now have the following early introductions to research:

Semester	Activity	Deliverables
Fall (1st)	Intro to research	10 p proposal: independent
Spring(2nd)	PhD research proposal	15 p. collab. proposal: PhD plan
Spring (4th)	Progress report	Oral presentation to PhD committee
Fall (5th)	Preliminary exam	PhD progress & plans (document) and presentation to PhD committee

Taken together, these activities constitute a broad and continuing "Introduction to Research" including considerable practice opportunities in writing proposals (3) and delivering oral presentations (4). These formal structures guarantee that all topics central to setting the stage for a successful research PhD experience are encountered early in what is typically a five year effort.

This formal, "forced convection" approach is, we argue from experience, more likely to produce a prepared PhD initiate that the traditional, much less structured approach of simply joining a lab group, beginning lab research, and "swimming or sinking" in a nearly solo effort, otherwise known as "learning by osmosis."

Our formal approach is consistent with recent studies of "How People Learn" (2,3), Here Donovan, Bransford and Pellegrino argue that "To develop competence in an area of inquiry, students must (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in the context of a conceptual framework, and (c) organize knowledge in ways that facilitate retrieval and application"

We argue that our early introduction of literature searching and reading reviews and original articles centered around a simple hypothesis provides opportunity to initiate foundation knowledge construction, that the conceptual framework of writing in proposal
format provides a focus for the student to demonstrate "understanding of facts and ideas in the (research) context", and that the written proposals and oral presentations repeatedly force the student to "organize knowledge in ways that facilitate retrieval and application."

The motivations for moving to our current two semester configuration were several, and we indicate our responses to each:

Faculty: Desire earlier start on (funded) PhD research
Add: 2nd semester PhD proposal
Graduate students: Seek earlier engagement with advisor and PhD committee
Add: Advisor for PhD proposal (2nd semester)
Add: Advisor to 2nd semester course faculty committee
Add: Presentation in 4th semester to PhD committee

Both courses require that student construct a research proposal. The distinctive differences between the courses are:

Fall proposal demonstrates originality (student solo effort), while spring writing demands collaborative conversations with advisor.
Fall paper is accompanied by a 15 minute class presentation followed by
graduate student questions and instructor written critique. The spring proposal is presented and defended in a one hour oral exam before four faculty including instructor, PhD advisor and at least one other member of the prospective PhD committee.

We believe that the student, having prepared the fall proposition on his own, is now in a strong position in the spring to crystallize advisor conversations and readings into a fruitful PhD proposal. Similarly, having faced instructor critique and classmate questions in the fall oral presentations, the student is better prepared for the more rigorous spring proposition defense in front of a faculty committee.

Student fall paper topic selection

Students are free to select their fall topics, as with our earlier proposition course[1]. Student topic selections for the fall 2009 and 2010 independent proposal efforts included a broad range of titles, which nonetheless could be classified as bio-related, materials-related, or kinetics and reactors (Tables 1a and 1b).

Table 1a
Titles for fall 2009 CHE 596 papers

Bio-related
1. Sulfomethylation as a pretreatment of corn stover for ethanol production
2. Influence of particle shape on the effectiveness of pectin-chitosan-alginate nanoparticles as drug carriers
3. Simulation of the piecewise synthesis of the protein G-ß-hairpin
4. Molecular dynamics study of mutations in amyloid ß-proteins
5. In vivo examination of chitosan-hyaluronic acid hydrogel as a cartilage regenerative scaffold
6. Enzymatic digestion of oxygen-functionalized hydrocarbons
Materials related
7. Modified approach for modeling animal bone demineralization process
8. Single-walled carbon nanotubes as foam stabilizers
9. Tandem solar cells on flexible substrates
10. Synthesis and analysis of microrods for stabilization of emulsions
11. In situ chemical polymerization of MES-PPV in carbon nanotubes for hybrid organic-inorganic solar cells
12. Bio-inspired solvent-free dye-sensitized solar cell
13, Carbon-nanotube reinforced hydroxyapatite bioceramic loaded with tetracycline
14. Gas phase synthesis of carbon nanodendrimers
15. Fabrication of patterned superhydrophilic/superhydrophobic substrates with photoinduced self-cleaning property
16. Manipulation of surface wettability between superhydrophobicity and superhydrophilicity on zinc films
17. Surfactant effects on electrospinning of alginate solutions
18. Joule heating within liquid crystal-carbon nanotube dispersions Kinetics and Reactors
19. Bubble slurry column reactor for producing propionic acid with methanol from syngas at low temperature

Table 1b
Titles for Fall 2010 CHE 596 course

Bio-related

1. Increasing lipid productivity in microalgae cells via nutrient optimization
2. Nanoparticle membranes via functionalization with single stranded DNA
3. Biocompatible chitosan-coated hollow hydrogel particles for drug delivery
4. Liposomes with curcumin-encapsulated cisplatin for dual anti-cancer drug delivery
5. Imunoglobulins from MS patients contain metallic subfraction that hydrolizes myelin glycoprotein
6. Buanol via co-fermentation of T. Resei, R. erythroplis and immobilized C. beijerinckii.
7. Expression of thermostable scaffoldin protein in S. solfataricus
8. Site-directed mutagenesis of oxygen diffusion pathways in C. reinhardtii hydrogenase for enhanced oxygen tolerance
9. Phototrophic biocathode for enhanced biomass photosynthesis

Materials-related

10. Photon modulated On/Off switch via light oxidative voltage (LOV) protein.
11. Organic solar cells via combined nanotube-bulk polymer heterojunctions
12. Cation-exchange membrane formation via film forming and hot press lamination
13. Increasing the efficiency of self-healing polymers
14. Lithium ion battery electrolytes for low temperature applications
15. Optimization of bulk heterojunction solar cells
16. Fullerene-coated carbon namotubes in ordered bulk heterojunction photovoltaic cells
17. Improved polymer composites via carbon nanotube reinforcement and selfhealing technology
18. N-substituted phosphoric acid doped polybenzimidazole protein exchange membrane for gas separations
19. Synthesis of transition metal-oxide heterostructured nanowires
20. Electrospun well–aligned nanofibers containing metal catalyst nanoparticles

Kinetics and Reactors

21. Tar and coke formation in hydrothermal gasification
22. Coupled partial oxidation and steam reforming for catalyzed hydrogen production
23. Modeling cellulose pyrolysis via molecular dynamics simulation
24. Heck reaction in supercritical carbon dioxide with palladium catalysts
25. Plasma assisted ammonia synthesis in a reverse-vortex flow gliding arc reactor

These self-selected fall topics for new graduate students indicate no discomfort with current research areas, regardless of how distant they may be from traditional undergraduate course materials. Part of the "frontier" aspect doubtless derives from the fact that many entering graduate students now have had an undergraduate research experience.

Pushing progress: Informal surveys

An in-class anonymous written survey motivates student progress and crystallizes planning through finite steps. This informal fall survey is conducted weekly in class and reported back to the student audience the same day (Table 2) until most queries are answered positively by most students. The public presence of a few "early bird" students typically galvanizes the others to "move up."

Table 2
Anonymous in-class survey

1. I have read at least one review article	(Yes/No)
2. I have re-read at least one review article	(Yes/No)
3. I have identified at least 5 original papers on my topic	(Yes/No)
4. I have read at least 5 original papers	(Yes/No)
5. I have chosen a (temporary) hypothesis	(Yes/No)
6. I have written a draft outline for my paper	(Yes/No)
7. I have found references for each part of my outline	(Yes/No)

Evaluation by graduate students

Formal course evaluations for the first three semesters of the independent, fall proposal and the first two of the collaborative spring proposal appear in Table 3(next page), a tabulation of our standard university course evaluations. These two writing courses fair well compared to our other department graduate courses (including reactors, transport, thermodynamics, and applied mathematics) and to the 1-5 absolute standard of our evaluation scale. Given the apparent initial hostility of new graduate students toward technical writing, these end-of-semester evaluations represent a significant achievement.
Importance of feedback.

For our earlier, one semester proposition course (1), students rate as most valuable the "writing the rough draft, comments received on the rough draft, and giving a practice talk." Rated as generally helpful were "doing a literature review; writing the proposal outline (with references); preparing the technical presentation, and class questions after the practice talk." These qualitative reflections indicate that continual, formative feedback for every phase of proposal construction is important. The formal deliverables are the final paper and presentation and defense, but the greatest learning appears to have been in the exercises and feedback leading up to these final products.

Table 3
Graduate student course evaluations: (Grad course / grad course dept average)

Course: (5.0 max)	Intro to Research			PhD proposition	
	Fall semester			Spring semester	
(% student participation)*	(84)	(65)	(46)	(67)	(47)
The instructor…	F 08	F 09	F 10	S 09	S 10
1. …stated course objectives	4.4/4.6	4.5/4.5	4.6/4.6	4.6/4.3	4.8/4.5
2. was receptive outside class	4.6/4.9	4.2/4.3	4.5/4.3	4.4/4.3	4.6/4.4
3. explained difficult materials	4.3/4.3	3.9/4.0	4.6/4.2	4.4/3.9	4.6/4.3
4. was enthusiastic re/teaching	4.6/4.5	4.2/4.4	4.6/4.5	4.6/4.3	4.4/4.4
5 was prepared for class	4.2/4.6	3.8/4.4	4.5/4.6	4.6/4.3	4.0/4.4
6. gave prompt, useful feedback	4.4/4.3	4.2/4.0	4.5/4.3	4.3/4.0	4.2/4.2
7. used instructional technology	4.1/4.5	3.3/4.2	4.0/4.3	4.3/4.3	4.2/4.4
8 treated students with respect	4.6/4.6	4.4/4.5	4.8/4.6	4.5/4.5	4.7/4.5
9. was an effective teacher	4.5/4.5	4.1/4.2	4.7/4.3	4.4/4.1	4.3/4.4
The course …					
10. …readings were valuable aids	4.4/4.5	3.6/4.2	4.3/4.2	4.6/4.2	4.3/4.3
11. assignments aided learning	4.6/4.6	4.1/4.3	4.5/4.4	4.8/4.3	4.1/4.2
12. was intellectually challenging	4.4/4.7	3.9/4.4	4.3/4.6	4.8/4.4	4.6/4.5
13. improved subject knowledge	4.4/4.6	4.1/4.5	4.4/4.6	4.9/4.4	4.6/4.5
14. was excellent	4.3/4.4	3.9/4.2	4.3/4.3	4.4/4.2	4.3/4.3

* Student completion of online university survey is optional, (unfortunately) not mandatory.

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Accordingly, scheduling individual discussion times with students is important in emphasizing the pattern in research of ideation and critiquing. Three formal 20 minute discussion times with each student are scheduled for the following purposes:

1. After outline & hypothesis: "What is central hypothesis ? What are the key 2-3 papers for this proposal ? Why are these important?"
2. After draft submission and return of written critique: "Questions for instructor ? (or advisor?)
3. After submission of draft slides: Review/critique of all slides.

Instructor time commitment

These informal discussions are important to the student, and also constitute a substantial and necessary part of the instructor's time commitment to the course. For example, the fall two unit course includes two 20 minute sessions with each student, so for our two most recent years, class size was 20-24 students, hence 7-8 hours of discussions twice a semester. The final presentation at 15 min(fall) and 30 min (spring practice) and 1 hr.(spring final) /student add 5-6 and 30-36 hours of instructor contact per semester, respectively. These times commitments are partially offset by moving from 2 classes/wk to one/week as the semesters progress.

Similarly, feedback regarding oral presentations is important. In fall semester,

students complete a formal one page speaker evaluation form for each of our Monday departmental research seminars. Two days later, the first 10 minutes of our Wednesday class are devoted to discussing these evaluations to highlight what the seminar speaker did well, and where opportunities for improvement lie. First year students are particularly critical of speakers who fail to provide an opening introduction to the topic, to establish key vocabulary as well as an initial, accessible story line.

In the spring, our department hosts an annual Schoenborn Research Competition, named after our department's founding chair, Ed Schoenborn. Here, first year students again complete written critiques of the oral presentations by 6-8 PhD students in their final year, again followed by an in-class discussion of presentations. This research symposium also includes 24 posters by students near the mid point of their PhD work, with attendant poster evaluations and awards.

Collectively, these efforts establish a critical thinking atmosphere for research, in which every element (ideation, literature review, hypothesis generation and outline, drafting, final paper and oral or poster presentation) are subject to real time critiquing.

Evaluations: Faculty

After the first two academic years (08/09 and 09/10) of the present format, our faculty who had accepted new students in the two most recent years were surveyed to ascertain their assessment of the new spring student-advisor collaborative format for producing a PhD research proposal. Our questionnaire asked about changes in the speed and depth of advisor engagement, integration into advisor lab group, and encounters with the PhD committee.

The results in Table 4 (next page) show that faculty are overwhelmingly positive about the new format. The faculty have, necessarily, a longer experience in current and former proposal formats for the first year experience than do the grads. The table shows that the new format results in faster engagement with a PhD research topic, advisor conversations, integration into lab groups, and conversations with the PhD committees. We conclude that the new format fruitfully addresses the prior concerns of both our faculty and graduate students.

Spring proposition: An original or an echo ?

Graduate students are uniformly supported by outside grants. According, for each advisor topic offered to new students in our late fall student-advisor selection process, a funded proposal already exists. Whether the spring proposition course produces a novel proposal is suspect, but the defining purpose of spring is for the student to take ownership for framing his PhD research via his own efforts as well as conversations with his advisor. The spring mid-semester draft proposal is critiqued by both the course instructor and the PhD advisor. Thus the advisor feedback has substantial influence on both the direction and focus of the prospective candidate's research. Correspondingly, the spring advisor-student conversations required to initiate

and focus the proposition guarantee a substantial, early student engagement with the advisor, as the faculty results below indicate.

Table 4
Faculty Survey: Spring research proposition course

AS-agree strongly, A-agree, N-neutral, D-disagree, DS-disagree strongly

	AS	A	N	D	DS
SPRING PROPOSITION					
The spring proposition …					
1. …increased speed of student engagement with (Ph D) research topic	8	7	1	0	0
2. …increased speed/depth of engagement with research advisor	5	9	2	0	0
3. … increased speed of integration into lab group	5	6	4	0	1
4. …led to earlier formation of PhD committee	6	6	3	0	1
5. …led to earlier engagement with (some of) PhD committee	5	9	1	1	0
6. … allowed earlier advising/counseling of student by advisor	4	9	2	1	0
SECOND YR PRESENTATION TO PhD COMMITTEE					
The second year (January) presentation..					
7. …gave earlier student engagement with full PhD committee	8	2	0	0	0
8. … showed evidence of faster student progress in research	2	7	0	1	0

Whether such spring effort is productive can also be judged by student evaluations. In Table 3, responses to statements 10-14 illustrate graduate student satisfaction with what was learned from the spring proposals as the responses were among the highest in the table. No student has complained that the second, spring collaborative proposition was a duplicative or repetitive version of the fall independent proposal !

Relation to prior work

The author is not aware of similar, extensive first year writing courses in other graduate departments, although the requirement for research propositions per se is widely found, often near the end of a thesis rather than the beginning. The need for early formal training in research writing is evident from a comment by Villareal [3]:

> "Scientific writing, like so much in academia is an acquired skill. It seems that transmitting writing skill is essential among the various aspects of scientific training. Most of my colleagues will agree that the one chore eliciting most consternation is the effort it takes to transform a young graduate student's first draft into a publishable manuscript."

Our view is that opportunity for such writing should not wait until the concluding years of PhD research, but rather begin on the first fall day of the graduate experience. While engineers and scientists are not widely regarded as willing writers, the fact that "student writers often do better work when their readings reflect their special interests"[4] indicates that the stereotype of the reluctant writer is incorrect, at least in graduate research.

Conclusions

Research is the dominant activity of graduate programs Consequently, formal training in aspects of research should be a logical part of first year graduate study. The present article illustrates how to smoothly engage new graduate students with their research topics and committees through construction, presentation, and defense of several written propositions. The courses described here have been taught in one form or another for twenty years, and have been strongly accepted and endorsed by both new PhD graduate students and their faculty advisors as the surveys reported here indicate.

These two courses could easily be taught elsewhere. Graduate student opportunity to write creative papers about research has been repeatedly shown to be productive via our twenty year history of these offerings, now to the order of 300 graduate PhD candidates. The total teaching load for such a course is similar to that for any three unity traditional offering. What is most different and required is the presence of an instructor dedicated to enhancing each student's story telling skill in the research domain.

Acknowledgement

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