CATALYZING THE STUDENT-TO-RESEARCHER TRANSITION:

Research Initiation and Professional Development for New Graduate Students

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My retired colleague, Richard Felder, used to joke that "The only skilled vocations for which formal training is not required are being a parent or a university professor." His career, long focused on how we teach, has helped lead to a revolution in teaching methods in engineering, as summarized in his new book with Rebecca Brent, *Teaching and Learning STEM: A Practical Guide* (2016). However, implicit in the title of professor is also the activity of research, and here the pace of formal educational progress has been substantially slower. Only in the last several decades has there begun to be a focus on professional development, technical writing, and presentation courses for graduate students as they enter their graduate research studies.

In the early 1990s, our department launched a new graduate course titled "The Research Proposition" in which incoming first-year graduate students would create, write, and defend an independent research proposal, described earlier in this journal.[1] To this well received offering, we subsequently added professional development topics including research ethics, intellectual property and patents, and the laboratory notebook.

Other single-course graduate offerings involving professional development and/or research writing have appeared with diverse titles and emphases. These include courses describing research methods (Burrows and Beaudoin[2]), theory and methods of research (Holles[3a,b]), research proposals in biochemical engineering (Harrison, et al.[4], Aucoin and Joicoeur[5]), as well as more sharply focused graduate topics including the critiquing of journal articles (Hill[6] and Minerick[7]), and developing oral communication skills (Wilkes[8]). In addition to courses, proposal writing during graduate studies has been previously required, *e.g.*, at Princeton near the end of a Ph.D. research, and at Berkeley via oral defense of a one-page proposal in winter quarter of the first year.

Departmental seminars have also been utilized in the service of professional development for (all) graduate students. Aris[9] reported a vehicle to broaden graduate education through themed seminars. One-time examples of these Minnesota experiments included "A Broader View of Research at the University," "The Science of Scholarship," "Variety of Academic Experiences," and "Analysis of Technology and Social Change." Similarly, Madihally expanded his department seminar topics to include technical writing, engineering ethics, intellectual property and patents, cultural diversity, and safety.[10a,b]

While our original, independent research proposition course[1] engaged the student in technical writing and presenting, it did not connect directly with either the Ph.D. advisor or the eventual thesis area. Both faculty and new graduate students sought an earlier engagement with research planning. The students also requested earlier engagement with their Ph.D. research committees. Thus motivation for our newer, second course was born.

COURSE SEQUENCE

As successful as the single-course approaches described above have been, there was lacking a formal mechanism to routinely transfer such formal learning into the informal

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atmosphere of advisor/advisee conversations and research group activities, *i.e.,* in integrating that formal knowledge into the graduate research experience, and demonstrating that integration. We report here such an achievement via a two-semester, first-year course sequence, CHE 701-702, in which the new student first composes, as before, an independent Fall proposal (CHE 701), and a newer Spring course wherein a second proposal—a nascent Ph.D. plan—is written by the student via collaborative consultation with her research advisor, and finally defended orally before a faculty committee (CHE 702). As the second semester also includes three units of independent research and entry into the appropriate research group, this two-course sequence achieves a seamless transition for the student, from the first-semester research initiation into second-semester Ph.D. advising and the long-term research group and laboratory. The new format has been taught for seven years to a total of approximately 150 first-year Ph.D. candidates.

TABLE 1
Curriculum and Percent Research Activity by Graduate Semester

Semester	Name	Courses (units)	Percent research (Based on credit hours)
First	**CHE 701**	**Introduction to Research (2)**	18
	CHE 711	Applied Mathematics (3)	
	CHE 713	Thermodynamics (3)	
	CHE 717	Chemical Reactors and Kinetics (3)	
Second	**CHE 702**	**Ph.D. proposition (2)**	45
	CHE 715	Transport Phenomena (3)	
		Teaching Assistant (3)	
	CHE 895	**Research (3)**	
Third	**CHE 895**	**Research (9)**	75
		Teaching Assistant (3)	
Fourth, etc.	**CHE 895**	**Research (12)**	100

Five-year curriculum

The first two years of the full Ph.D. curriculum appear in Table 1, which shows the relation of these formal courses, CHE 701–702, to conventional graduate courses and research, and the total percent of research-related effort vs. semester, increasing from 18% to 100% over the first four semesters.

In addition, we have added an oral progress report to each student's Ph.D. committee in January of the second year, which is followed by the customary university preliminary exam at the beginning of year three. This change continues the earlier contact with the student's Ph.D. committee, allowing for more reflection and discussion among the committee members at a time that may provide influence on the eventual path of the proposed research.

Taken together, we now have the new graduate student writing three research proposals and giving four oral research presentations within the first two years (Table 2[11]). These provide a full, formal initiation into connecting with research advisor, undertaking research study, and integrating into the lab group. To use a chemical engineering metaphor, these activities catalyze achievement of the student-to-researcher transition.

The following sections discuss the Fall and Spring course formats, and the faculty and graduate student evaluations, of this two-semester, first-year experience.

COURSE STRUCTURES

In both semesters, a proposal is required with a structure including the following six elements:

1. *Hypothesis (1-2 sentences indicating the assertion to be tested)*
2. *Literature background, which provides the plausibility and justification for the hypothesis*
3. *Operational statement (1-2 sentences) disclosing the particular system(s) that will be used to test the hypothesis*
4. *Methods and procedures*
5. *Expected results (paragraph)*
6. *References*

This structure produces a document that meets two requirements: The first half of the proposal demonstrates that the student has found a research problem, and the second portion should establish that the student has the competence to solve it. The second-semester paper also includes a summary page, written in the customary NSF proposal format, containing final paragraphs on Intellectual Merit and Broader Impact.

The lecture topic schedules for each two-unit proposal course are shown in Tables 3 and 4. We now discuss the distinctive features of each offering.

INTRODUCTION TO RESEARCH (FALL SEMESTER, CHE 701)

As with our original, single-semester courses,[1] the dominant activity remains construction of an independent research proposal with instructor review/comment on writing progress. The assignments are eight: literature search and ideation, critique of a research article, proposal outlines including hypothesis and references, individual discussions of hypothesis and three key articles, proposal drafting, critique and revising for final proposal, construction and individual review of draft slides, and an oral presentation to instructor and class, with following questions and answers. The calendar of detailed, appropriately spaced due dates has led to satisfactory completion of research proposals year after year. Only two of >150 Ph.D. candidates have failed to cross the finish line in this proposition course.

In addition, the current offering includes the professional development topics of research ethics, technical writing styles (objective, persuasive, critical), advisor expectations, intellectual property, laboratory notebooks, slide preparations, and oral presentations (Table 3).

The incoming graduate students each Fall have interests including kinetics and catalysis, biochemical engineering, and materials, as reflected in their CHE 701 proposal topics from recent semesters. They choose research advisors on the end of first semester, so their

TABLE 2
Proposal and Presentation Calendar (years one and two)[11]

Season	(Semester)	Activity	Deliverables
Fall	(1st)	Intro to research	10 p. proposal + oral defense: independent
Spring	(2nd)	Ph.D. research proposal	15 p. proposal (Ph.D. plan) and defense: collaborative
Spring	(4th)	Progress report	Oral progress report to Ph.D. committee
Fall	(5th)	Preliminary exam and presentation to Ph.D. committee	Ph.D. progress & plans (oral + written)

TABLE 3
CHE 701 Introduction to Research (2 units)

Week	Lecture Topics and Assignment Due Dates
1	Research: The heroic quest
	Research ethics: canons and cases
2	Electronic literature searching
	Identifying a research topic
3	Research proposal structure and style
4	Ph.D. thesis: structure and style
	Writing styles: concise, complete
5	Critique of research article
	DUE: Literature search (10-15 papers, 1-2 reviews)
6	Advisor expectation of Ph.D. candidate
	DUE: Critique of research article
7	Intellectual property and patents
	DUE: Proposition outline with references (2 pages)
8	The laboratory notebook
9.	DUE: Individual discussions with instructor
10	Research heroes
	DUE: Proposal draft (10 pp + references)
11	Revising technical prose
12	Oral presentation tips
	DUE: Final proposal
13.	DUE: Draft slides & discussion with instructor
14	DUE: Oral presentations (15 min/student)
Note: All students continue into CHE 702 spring semester	

TABLE 4
CHE 702 The Ph.D. Research Proposal (2 units)

Week	Lecture Topics and Assignment Due Dates
1	Review calendar/schedule advisor meetings
2	How to Write Methods section (review)
3	DUE: Schoenborn Research Symposium (full day)*
4	Incorporating engineering analysis into proposal
5	DUE: Literature search (10-15 papers, 1-2 reviews)
	Proposal committees formed (four faculty)
6	DUE: Individual discussions with instructor
7	Ethics in proposal writing
8	DUE: Proposal draft (15 pp + references)
	Managing the research group
9	Video presentations of research
10	Oral presentations II
11	DUE: Final proposal (distributed to faculty)
12	DUE: Draft slides & discussion with instructor
13	DUE: Practice presentation to class (30 min)
14	DUE: Oral presentations to faculty (60 min/student)

*The department sponsors an annual Schoenborn Research Symposium honoring its first chairman, Ed Schoenborn, and featuring about 15 oral presentations by graduating Ph.D.s as well as an extensive 35 poster session by 3rd and 4th year candidates. CHE 702 students evaluate each student speaker, and discuss these presentations in the following CHE 702 class.

Fall CHE 701 topics are independent of advisor selection. The modernity of their themes reflects the fact that 70-90% of the incoming graduates now have prior undergraduate and/or summer research experience.

THE PH.D. PROPOSAL (SPRING SEMESTER, CHE 702)

The first-year graduate student will have chosen a Ph.D. advisor by first semester's end. The Spring semester challenge is now for the student to develop, via collaborative conversations with the new advisor, a 15-page proposal and plan for the Ph.D. research (Table 4). In principle, the new writing is that of the student, but now the proposal draft receives more critical review and feedback: Both the course instructor and the new Ph.D. advisor critique the draft proposal. Next comes a dress rehearsal, a practice presentation (20-25 min) to the class with questions and answers (5-10 min). The student's final presentation to a faculty committee is a one-hour event, typically comprising a 20-25 min. presentation and a 20-25 min. Q & A period by the faculty committee, followed by a 10-minute closed committee meeting. The course instructor chooses these committees to include the advisor(s) and other faculty familiar with the research area. The instructor is a member of all committees, and is moderator for the Q & A sessions. The common research interests of the faculty within any given committee have also led to substantial discourse among committee members, *i.e.*, conversations going well beyond student-faculty exchanges.

The second-semester simultaneous activities of Ph.D. proposal writing (CHE 702) and research lab integration (advisor conversations, doctoral research) (CHE 895) thus smoothly transition the new graduate student from his first-year classes into his technical areas of Ph.D. focus and into the social domain of advisor and lab group with whom the student will be engaged for the subsequent 3–4 years of study. The percent activity in research courses (CHE 701, 702, CHE 895) grows steadily from the initial proposition course (18% effort) in the first semester to full effort (100%) in the fourth semester, as shown earlier in Table 1.

EVALUATIONS

Student CHE 702 proposal and presentations

For the final presentation in the second-semester course, CHE 702, we utilize the evaluation form shown in Table 5, which asks for assessment of both the written document and

TABLE 5
Evaluation Form: CHE 702 (A = excellent, B = good, C = needs improvement)

Student_____ Faculty evaluator_____

	Possible Grade			Assigned Grade
	A	B	C	_____
Written Document				
Knowledge of "state of the engineering science," perspective, critical analysis of existing literature (10%)	0.4	0.3	0.2	_____
Suitability of selected research problem: originality, feasibility of success (10%)	0.4	0.3	0.2	_____
Effectiveness of proposed research plan: understanding of relevant physical and chemical phenomena, chance of success, methodology current and viable (10%)	0.4	0.3	0.2	_____
Quality and effectiveness of writing: conciseness, logic, clarity (20%)	0.8	0.6	0.4	_____
Creativity: degree of innovation in proposal (15%)	0.6	0.45	0.3	_____
WRITTEN SUB-TOTAL				_____
Oral Presentation				
Quality and effectiveness of presentation: conciseness, logic, clarity, impact, thoroughness (20%)	0.8	0.6	0.4`	_____
Knowledge of field of research topic (5%)	0.2	0.15	0.1	_____
Mastery of chemical engineering principles (5%)	0.2	0.15	0.1	_____
Creativity in responding to questions (ability to think on feet) (5%)	0.2	0.15	0.1	_____
ORAL SUB-TOTAL				_____
OVERALL SCORE				_____

the oral presentation, with the former representing about 2/3 of the entire course grade, and the latter the remaining third A total grade of 3.0 or higher is considered satisfactory, as with other graduate courses. Lesser averaged scores lead to recommendation to first pursue an M.S. thesis; upon thesis completion, candidate and advisor may petition for the student's readmission to Ph.D. program.

While the first semester provides an introduction to research and research writing, the second constitutes a deeper research engagement for the following reasons:

1. *The second proposal represents a research plan for the Ph.D., created in consultation with an established faculty advisor.*
2. *The faculty committee that reads the written proposal and poses all questions following the final oral presentation represents the student's nascent Ph.D. committee, and thus provides an earlier engagement of student and thesis committee members than typical.*
3. *In anticipation of a more critical faculty Q & A session than that provided by the class in the first semester, a practice presentation (full dress rehearsal) to the class/instructor is given the week before the final presentation.*
4. *Over the semester, the student will have become integrated into her new research group by taking three units of research in parallel with the second proposition course. The more senior grad students in each group routinely ask each first-year grad to give yet another, earlier practice presentation that they critique. This practice also furthers integration into each research group.*

The second course thus crystallizes activities that were lightly modeled in the first-semester course.

Faculty evaluation of CHE 702[11]

Following the 2009-2010 and 2010-2011 offerings of this newer course, the faculty were surveyed in 2011 and asked to compare Ph.D. student activity under the original one-semester research proposition course[1] with the new two-semester sequence. The results appear in Table 6, which demonstrates "that the new format results in faster engagement with a Ph.D. research topic, advisor conversations, integration into lab groups, and conversation with the Ph.D. committees."[11] Statistically, 84% (37% + 47%) of responses were positive, 11% were neutral, and only 5% were negative. In engineering parlance, the formal address of these intangible subjects via this two-course sequence demonstrates that learning about research by "forced convection" is more efficient than the traditional route of "learning by osmosis."

TABLE 6[11]
Faculty Survey: Spring CHE 702 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 Ph.D. committee	6	6	3	0	1
5. …led to earlier engagement with (some of) Ph.D. committee	5	9	1	1	0
6. … allowed earlier advising/counseling of student by advisor	4	9	2	1	0
SECOND YR PRESENTATION TO Ph.D. COMMITTEE*					
The second year (January) presentation...					
7. …gave earlier student engagement with full Ph.D. committee	8	2	0	0	0
8. … showed evidence of faster student progress in research	2	7	0	1	0
Total	43	55	13	3	2
Percent	37	47	11	3	2

* Note: 16 faculty advised students who had completed 1 full graduate year(questions 1-6), but only 10 had students who had completed 2 full years(questions 7-8) at the time of this 2011 survey.

GRADUATE STUDENT EVALUATION OF CHE 701-CHE 702 SEQUENCE

We utilized three surveys to reflect graduate student impressions of these two courses: (i) a university standard form (generic), (ii) a course-specific survey for the 2014-2015 cohort of 21 students, and (iii) a reflection survey for senior graduate students in their years 2-5 of study. The data from these surveys appear in Tables 7, 8, and 9/10, respectively.

Student (university) course survey

New engineering graduate students are not known for their interest in either technical writing or oral presentations. This stereotype aside, formal course evaluations

used online in all conventional NCSU academic courses were also used to measure graduate student evaluation of the new course sequence, including characteristics of both the instructor and the courses themselves. Table 7 summarizes these graduate students' responses for our most recent full academic year (Fall 2014 + Spring 2015).

TABLE 7
Graduate student course evaluations: (Course / dept average)*

Course: (5.0 max):	Intro to Research (CHE 701) Fall semester (2014)	Ph.D. Proposition (CHE 702) Spring semester (2015)
(% response)	(38%, 11/29)	(50%, 11/22)
The instructor		
…stated course objectives/outcomes	4.7/4.7	4.6/4.6
…was receptive outside classroom	4.5/4.3	4.5/4.2
…explained material well	4.9/4.5	4.7/4.3
…was enthusiastic about teaching	4.9/4.7	4.7/4.3
…was prepared for class	4.9/4.7	4.6/4.6
…gave useful feedback	4.1/4.4	4.5/4.3
…treated students with respect	4.9/4.7	4.5/4.3
…was an effective teacher	4.6/4.5	4.5/4.3
The course		
…readings were valuable aids	4.6/4.2	4.3/4.0
…assignments aided learning	4.7/4.5	4.5/4.2
…improved knowledge of subject	4.6/4.7	4.5/4.3
…was excellent	4.3/4.3	4.4/4.1
* Student completion of online university survey is optional (unfortunately), not mandatory.		

TABLE 8
CHE 702 Questionnaire (Spring 2016)

The syllabus for CHE 702 is attached for your information.

(AS-Agree strongly, A-Agree, N-Neutral, D-Disagree, DS-Disagree strongly)

Through course CHE 702, I have:	AS	A	N	D	DS
-increased my ability to write technical proposals	(14)	(5)	(1)	(-)	(-)
-established positive working relationship with my advisor	(10)	(9)	(1)	(-)	(-)
-become well integrated into my research group	(8)	(5)	(7)	(-)	(-)
-become comfortable giving technical presentations	(5)	(13)	(2)	(-)	(-)
-become proficient at creating visual presentations	(8)	(10)	(2)	(-)	(-)
-become comfortable presenting my plans to faculty	(4)	(14)	(2)	(-)	(-)
-transitioned from new grad student to prepared researcher	(5)	(12)	(2)	(1)	(-)

The results clearly demonstrate that new graduate students find these courses—dedicated to technical writing and oral presentations—are as worthwhile as conventional graduate courses in advanced mathematics, thermodynamics, reactor design, and transport phenomena. For this seventh offering of our two-course sequence, these recent 2014-2015 results and the departmental averages are both slightly higher than those reported in our earlier summary of 2011.[11]

First-year course-specific survey

CHE 702 graduate student survey

Our title claims that the CHE 701-702 sequence catalyzed the transition of new graduate student to prepared researcher. The course CHE 701 Introduction to Research clearly emphasizes the central concept: discovery of new material through hypothesis and testing. The key feature of the spring CHE 702 course is use of advisor collaboration in new proposal creation. We tested the title hypothesis by surveying the Spring 2016 CHE 702 class of 21 new Ph.D. aspirants. The survey, capturing 20 of 21 enrolled students (95% yield) and summarized in Table 8, indicates full validation of our opening hypothesis, as these data show that among the 20 participants,

- *95% agree (A) or agree strongly (AS) that through CHE 702 they increased competence in proposal writing and established a positive advisor-advisee relationship,*
- *90% agreed or agreed strongly that they became comfortable giving presentations to both their research groups and to faculty, and in creating visual presentations,*
- *85% agreed or agreed strongly that through CHE 702 they have "transitioned from new graduate student to prepared researcher."*

Less successfully, but still

with positive outcome, 65% agreed or agreed strongly that they had "become well integrated into their research group." Clearly, this socialization process takes time; the new circumstances within a research, rather than classroom, enterprise require more time than one semester to fully mature.

Senior grad student post-course survey

The new sequence having been practiced for seven years, we also surveyed via email the senior graduate students, those in years 2-5 of their Ph.D. graduate work. We solicited responses from our 91 senior graduate students, and received responses from 35 (40% yield). While the survey yield was only moderate, the distribution of responses from students of all years 2-5, of both genders, and of U.S. and international (Table 9) is a good representation of our current departmental demographics. We asked them to identify which of those proposal, presentation, and professional development topics from their first-year formal research courses, CHE 701 and 702, were most useful to them.

The senior graduate student results shown in Table 9, part A, indicate that activities of outlining, drafting, literature searching, and presentations were most useful, with feedback on these activities somewhat less important. This result differs from that for our single-course experiments,[1] in which first-year students reported that feedback from the instructor on these same activities was most important. We presume that the increased maturation of these senior students provided the shift in survey outcomes.

The utility of the professional development topics was also similarly reflected (Table 9, part B). Here activities (writing, conversing, and presenting) were seen as most useful, while still useful, but less so, were the relatively passive topics of research ethics and intellectual property, with the occasional actions involving the laboratory notebook and lab management seeming least important. Doubtless, a few years in industry will elevate the last topics to a higher level.

The final portion of Table 9, part C, shows the profile expected of active, mature researchers: nearly half their time spent doing active research, about equal time dedicated to reading, writing, and presenting, and substantial conversation levels with peers and Ph.D. advisors.

TABLE 9
Senior Grads
(years 2–5 of Ph.D. program; 35 responses)

I am preparing an article summarizing the department's experience with the CHE 701-702 sequence, and invite you to participate in this short, anonymous questionnaire regarding the impact of these courses on your NCSU research and professional development paths.	
Your year: 2nd (10) 3rd (8) 4th (7) 5th (10)	
Gender: Female (10) Male (25)	
Citizenship: US (24) International (11)	
A. In retrospect, what proposal and presentation aspects of CHE 701-701 have been most useful to you ? Check up to five boxes.	
proposal drafting	(27)
proposal outlining	(24)
electronic literature searching	(21)
final presentations	(20)
practice presentations	(15)
advisor feedback	(14)
draft slides/feedback	(14)
ideation/hypothesis generation	(13)
instructor feedback	(12)
B. What professional development topics were most useful ? Check up to three boxes.	
technical writing practice	(24)
advisor/advisee relations	(23)
oral presentation practice	(22)
research ethics	(14)
patents/intellectual property	(6)
laboratory notebook summary	(5)
laboratory management (2014-2016)	(3)
C. Looking back over all of your post-first year time, what percent of your time would you estimate you spent on the following activities: (response should add to 100 %)	
	Percent (average of 35)
lab and computer research	43
research writing/revising	12
literature reading	10
lab management	8
advisor conversations/feedback	7
peer research conversations	7
oral preparations & presentations (NCSU group)	5
oral preparation & presentations (external)	5
proposal writing	3
Total	100

Beyond the closed-end responses on the questionnaire, free responses were solicited from these seniors using the following prompt: "A brief philosophy of research is "Plan, Execute, and Publish." The selected responses appear below in Table 10 A-C (respondents identified by year in program). These reflections from our senior graduate students indicate that the newest of our first-year proposal courses, CHE 702, had a substantial impact that carried through all the years of Ph.D. study, and included all three major dimensions of research: Planning, Execution, and Publication.

TABLE 10
Replies: "In what ways, if any, has CHE 702 helped you to..."

Plan Ph.D. research: *(year of graduate study shown in parenthesis)*
My project has changed a couple times since CHE 702, so I have had to re-plan. The outline format taught in that course has been helpful. (2nd)
Helped me to think a big picture and make a story about my project. (2nd)
It helped open initial line of communication with my advisor regarding my project. (2nd)
I think the outline part was really helpful. it makes the writing process more organized. Also, my literature searching skills were improved. (2nd)
The focus on outlining in CHE 701-702 with specific due dates just for outlines helped me to learn the power of effective planning. I outline everything now. (5th) (5 similar comments)
Planning is a much more important step in the research process than anticipated by researchers, and effective planning and reading save massive amounts of time in the lab.… This advice has kept me more diligent as a reader of the literature, and ultimately helped provide me with good, new ideas as well as discard poor ones. (4th)
Doing the literature searches and understanding what questions still remain unanswered is helpful. This enables students to identify areas where they should be focusing on research(5th) (9 similar comments)
Execute your Ph.D. research:
Focusing on keeping a lab notebook has helped me see progress and catch errors that otherwise would have been hard to spot. (2nd) (3 similar comments)
Learning about different advising styles in CHE 702 has helped me understand my advisors better when discussing research. (2nd) (3 similar comments)
I have been able to follow the outline in my proposition to execute my Ph.D. research. (2nd)
CHE 702 was helpful in knowing how to go about dealing with others and how to manage people and space conflicts in lab. This was particularly relevant for me since I became partially responsible for lab safety during my second year. (2nd)
While the courses helped plan, research funding required constant revision of experimental plan. Research priorities change frequently. (4th) (3 similar comments)
I don't think CHE 702 helped me execute research all that much. Hands-on experience and training in the lab has helped with that, and I got that mostly in the summer after CHE 702. (5th) (3 similar comments)
Limit your variables. (5th)
Publish your Ph.D. research:
Proposition writing helped me understand the technical aspects of writing research papers. (3rd) (3 similar comments)
There are many other groups out there reading the same literature and working in the same research areas as you are. Don't sit on data until it is too late to publish it. Getting scooped is pretty frustrating! (5th)
Write up results now. (5th) (5 similar comments)
The most important take away for me was how to handle and respond to feedback regarding final research products. (5th)
Both oral presentations at conferences and written publication benefitted from what I have learnt from CHE 702. (5th)

WHY WRITE EARLY?

The completion of two proposals in the initial year of graduate study may seem presumptuous. After all, why should a new graduate student write about doing research when her prior experience as an undergraduate may have been little to none? We agree with an answer suggested by Montgomery[12] in *The Chicago Guide to Communicating Science*:

There is "the widespread notion that 'to write clearly, you must first think clearly.' This sharp little maxim may appear logical, but it is really rubbish. No matter how rational your thought may be (or appear to be) on a particular problem, no matter how detailed your intentions and plottings, the act of writing will almost always prove rebellious, full of unforeseen difficulties, sidetracks, blind alleys, revelations. Good, clear writing—writing that teaches and informs without confusion—emerges from a process of struggle, or if you prefer, litigation.

"Most often, the terms of the formula given above need to be reversed: 'clear thinking can emerge from clear writing.' Imposing order by organizing and expressing ideas has great power to clarify. In many cases, writing is the process through which scientists come to understand the real form and implications of their work."

END NOTES

This novel course sequence provides a vehicle by which the new research student quickly transitions from undergraduate to graduate, from being a solver

of closed-end problems to a creator of open-ended research themes, from being only a technical reader to becoming also a creative writer, and from being locked into a competitive, often solo undergraduate learning experience to becoming a socially engaged, open, and sharing graduate professional.

The instructor teaching load for each of these two-unit graduate courses is approximately that of a conventional three-unit engineering course. While the Fall semester begins with two lectures per week, it moves to one weekly meeting as time for one-on–one conversations regarding hypothesis, outline, and draft slides appears, and as final presentations occur. Similarly, Spring starts with only a weekly meeting, but intensifies as the course arrives at the practice presentations (21 students × 30 min/student = 10.5 hrs), and the final week of 21 hourly presentations to the committees. Should it be regarded as a triathlon of lecturing, conversing, and listening?

ACKNOWLEDGMENT

I again thank my faculty colleagues and the 150+ Ph.D. candidates who have helped to make this new sequence a pleasure to teach. The students' annual activity of conceiving, writing, and presenting 40-50 new proposal stories guarantees that these two courses never become stale to this instructor. This outcome probably has been realized by most teachers of creative writing courses, for the reason stated so clearly by R. Fulford in his book *The Triumph of Narrative: Storytelling in the Age of Mass Culture*[13]: "Storytelling is the mother of all literary arts, and anyone who reads must occasionally speculate on its enduring power."

REFERENCES

1. Ollis, D.F., "The Research Proposition," *Chem. Eng. Ed.*, **29**(4), 222 (1995)
2. Burrows, V., and S. Beaudoin, "A Graduate Courses in Research Methods," *Chem. Eng. Ed.*, **35**(4), 236 (2001)
3. Holles, J.H., (a) "Theory and Methods of Research (or How to be a Graduate Student)," *Proceedings* ASEE annual mtg, 2005; (b) "A Graduate Course in Theory and Methods of Research," *Chem. Eng. Ed.*, **41**(4), 226 (2007)
4. Harrison, R.G., "The Research Proposal in Biochemical and Biological Engineering Courses," *Chem. Eng. Ed.*, **40**(4), 323 (2006)
5. Aucoin, M.G., and M. Jolicoeur, "Is There Room in the Graduate Curriculum to Learn 'How To Be a Graduate Student?' An Approach Using A Graduate-Level Biochemical Engineering Course," *Chem. Eng. Ed.*, **43**(4), 306 (2009)
6. Hill, P.J., "Teaching Entering Graduate Students the Role of Journal Articles In Research," *Chem. Eng. Ed.*, 246 (2006)
7. Minerick. A., "Journal Club: A Forum To Encourage Graduate and Undergraduate Students To Critically Review the Literature," *Chem. Eng. Ed.*, **45**(1), 73 (2011)
8. Wilkes, G.L., "The Importance of Oral Communication Skills and a Graduate Course To Help Improve These Skills," *Chem. Eng. Ed.*, **46**(4), 251 (2012)
9. Aris, R., "Horses of Another Color—Some Notes on Seminars in a Chemical Engineering Department," *Chem. Eng. Ed.*, **12**(4), 148 (1978)
10. Madihally, S., (a) "A Novel Paradigm for Training Graduate Students in Soft Skills," *Proceedings* of ASEE annual mtg., 2011; (b) "Reviving Gradaute Students Seminars Series," *Chem. Eng. Ed.*, **45**(4), 231
11. Ollis, D.F., "The Research Proposition and Professional Development: Update On First-Year Graduate Student Preparation," *Proceedings* ASEE Annual mtg., Chicago (2011)
12. Montgomery, S.L., *The Chicago Guide to Communicating Science*, University of Chicago Press (2003)
13. Fulford, *The Triumph of Narrative: Storytelling in the Age of Mass Culture*, House of Anansi Press Limited, Toronto (1999) ❐