GRADUATE STUDENT TEACHING FELLOWSHIP PROGRAM

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In 1990, the DuPont Company, acting on advice from a panel of university faculty, initiated the DuPont Teaching Fellowship program in chemical, mechanical, and electrical engineering with the aim of giving graduate students a supervised in-class teaching experience. Six of these teaching fellows described their chemical engineering teaching experiences in *Chemical Engineering Education*.[1]

There have been some programs initiated to give graduate students some teaching experience as part of their graduate education. Many departments offer a course, often with the cooperation of the Education school, that covers the principals of effective education as described for engineers in the book by Wankat and Oreovicz.[2] Such a program—which incorporated a mentoring experience—is described in the paper by Baber, Briedis, and Worden from Michigan State University.[3] Another paper, by Sherwood, Peterson, and Grandzielwski, described in detail the successful experience of a graduate student at Washington State University.[4] Graduate student Julie Sherwood taught a semester course that was monitored by a faculty member who attended each lecture and provided feedback and planning assistance. In this paper we describe the experience of three departments with a graduate student teaching fellowship program initiated in the Department of Chemical Engineering at the University of Delaware in 1994 and successfully continued to this day.

UNIVERSITY OF DELAWARE

Based on their experience with Linda Broadbelt,[1] those involved in the DuPont Teaching Fellowship in Chemical Engineering (now Chemical and Biomolecular Engineering) at the University of Delaware began experimenting with their own Teaching Fellowship Program in 1994 using department funds to supplement the graduate stipend for the fellows. The faculty was convinced that giving graduate students an effective teaching experience would help complete an important part of the students' graduate education.

T.W. Fraser Russell *is the Alan P Colburn Professor Emeritus in the Department of Chemical and Biomolecular Engineering at the University of Delaware. He is a member of NAE and a registered professional engineer in Delaware. In addition to his successful research efforts in photovoltaics and multi-phase fluid mechanics he has coauthored three undergraduate texts for chemical engineering students. In recognition of his teaching efforts he has received a University of Delaware Excellence in Teaching Award, the AIChE Warren K. Lewis Award, and the ASEE Lifetime Achievement Award in Chemical Engineering Pedagogical Scholarship.*

Megan H. Argoe *is an administrative assistant in the Department of Chemical and Biomolecular Engineering at the University of Delaware. She has worked at the University of Delaware for 10 years, starting in the Department of Fashion and Apparel Studies. After being promoted Megan moved to the Department of Urban Affairs and Public Policy. She now is a critical assistant in the Department of Chemical and Biomolecular Engineering.*

J. Fraser Forbes *earned a B.A.Sc. (chemical engineering) in 1982 and an M.A.Sc. (chemical engineering) in 1984 from the University of Waterloo. In 1994 he received a Ph.D. in chemical engineering from McMaster University. Between his Master's and Doctoral degrees he worked primarily as a consultant in the food processing, wood products, and steel industries. In 1994, he joined Ryerson University and in 1996 moved to the Department of Chemical & Materials Engineering at the University of Alberta. He served as an associate chair in the department from 1998-2002 and has served as the department chair since 2002.*

Linda Broadbelt *is Sarah Rebecca Roland Professor in and chair of the Department of Chemical and Biological Engineering at Northwestern University. She received her B.S. in chemical engineering from The Ohio State University. She completed her Ph.D. in chemical engineering at the University of Delaware in 1994. At Northwestern, she was appointed the Donald and June Brewer Junior Professor from 1994-1996. Her research and teaching interests are in the areas of multi-scale modeling, complex kinetics modeling, environmental catalysis, novel biochemical pathways, and polymerization/depolymerization kinetics.*

Lynn Walker, now a faculty member at Carnegie Mellon University, was mentored by M.E. Paulitis in the introductory courses in Thermodynamics. Carlonda Russell, now employed by the DuPont Company, was a teaching fellow working with T.W.F. Russell in the Introduction to Chemical Engineering Analysis class in 1994. In the same year, Charles Roth was assigned to teach in Mass and Heat Transfer with A.M. Lenhoff and N.J. Wagner. Hank Ashbaugh, now a faculty member at Tulane University, was a fellow in Introduction to Chemical Engineering Analysis with T.W.F. Russell in 1996.

The positive experience with these first teaching fellows prompted the department to design a more formal program in 2000. T.W.F. Russell set up an endowed account to fund the Fraser and Shirley Russell Teaching Fellowship to honor his wife who died from cancer in 1998. This account provides a $3,000 stipend for the fellow and $1,000 to the fellow's faculty adviser for summer support for an undergraduate student. The department supplies funds to support additional department teaching fellows.

Graduate students were invited to apply with a short resume and their reasons for wishing to have the experience. A faculty committee was set up to evaluate the applicants and to assign the fellowship awards, which were set between $2,000 and $3,000 over and above their graduate stipends. The department chair assigns the fellows to those classes whose instructors will carefully supervise the assigned fellow.

The fellows are carefully monitored and are never in the class alone. At least one faculty member must always be present. Experience with fellows over the past two decades allows one to make the following observations:

All the fellows spend considerable time in preparation for the class they have been assigned to teach and participate fully in discussions with their faculty mentors.

The fellows' first lectures are well organized but almost always there is little or no interaction with the students in the classroom setting. However, they are very effective in one-on-one tutoring out of class.

After some coaching, fellows will begin to observe the class more carefully and ask students questions but when they begin to do so they frequently don't listen carefully to the answer.

The fellows are quick to learn and by the end of their experience they have become much better with in-class interactions.

It is very gratifying to see the change in the way the fellows approach classroom teaching after their supervised teaching experience. The experiences of some of the teaching fellows are described in their own words in Appendix 1.

It is critical that the teaching fellow not be considered as a resource to reduce the faculty member's teaching load. Faculty with a teaching fellow often devote more time to the course since they go over each lecture with the fellow before and after class. Teaching fellows typically teach between seven and 10 lectures in a semester, help supervise the teaching assistants, and work with the faculty on exam preparation. The fellowship program has had a positive effect not only on the fellows themselves but also on the other graduate students with whom they interact, since it fosters discussions about teaching and how to do it effectively.

To date the department has awarded 15 Fraser and Shirley Russell Teaching Fellowships and 20 department-sponsored teaching fellowships—14 recipients are now in faculty positions in the United States, Canada, the United Kingdom, and Chile: H. Ashbaugh at Tulane; W. Thielemans at University of Nottingham, U.K.; M. Snyder at Lehigh; Y. Lapitsky at University of Toledo; J. O'Donnell at Iowa State University; M. (McDonald) Staehle at Rowan; M. Helgeson and M. O'Malley at University of California, Santa Barbara; W. Medlin at University of Colorado; L. Walker at Carnegie Mellon; P. Tessier at Rensselaer Polytechnic Institute; S. Linic at University of Michigan; C. Gelmi at Pontificia Universidad Catolica de Chile, Chile; and J. Stanzione at Rowan. Several are in industrial jobs and some in post-doctoral studies.

UNIVERSITY OF ALBERTA

T.W.F. Russell also endowed the Fraser and Shirley Russell Teaching Fellowship program at his alma mater, the University of Alberta, in 2006. The Chemical and Materials Department at Alberta supplements the endowment funds. Nine fellows have been supported to date. Two former fellows are currently teaching: Veeramani Chidambaranathan at IIT, Roorke, and Misha Monder at IIT, Hydrabad.

Although the Fraser and Shirley Russell Teaching Fellowship is relatively new at the University of Alberta, it has helped emphasize the importance of teaching and striving for teaching excellence in the department. This teaching fellowship has become a crucial catalyst in sparking discussion of teaching within Alberta's graduate student community, as well as between graduate students and their supervisors. The program at the University of Alberta is very similar in its operation to the University of Delaware model. Most teaching fellows work closely with the faculty mentor who is teaching a specific course. The model is that a teaching fellow offers a small number of lectures, with the course instructor providing guidance prior to and after each lecture. The course instructor is present in the classroom while the teaching fellow lectures. One unexpected success of the teaching fellowship is that a few of our more adventurous teaching fellows have expressed a very strong desire to take on an entire course. For those whom we feel capable of meeting this challenge, we assign at least one teaching mentor and ask that a mentor be present in the classroom at all times. Our undergraduate students have "bought into" the teaching fellowship program and provide valuable feedback via direct suggestions, as well as interim and formal course teaching evaluations. In summary, although

The best part about it is feeling this joy of teaching and educating students.

—Nemanja Danilovic

our experience with the teaching fellowship has only been for a few years, we are starting to see some real successes. Perhaps the most important is an increasing enthusiasm for teaching in those graduate students who will go on to be the next generation of academics. See Appendix 2.

NORTHWESTERN UNIVERSITY

Linda J. Broadbelt, now Sarah Rebecca Professor and chair of Chemical and Biological Engineering, accepted a faculty position at Northwestern University when she graduated from Delaware. Partly as a result of her teaching fellow experience she was awarded the June and Donald Brewer Junior Professorship. She was instrumental in setting up what Northwestern University designated as a Teaching Apprentice Program. This program has to date graduated 33 apprentices. The following are now in faculty positions: Joe McCarthy, University of Pittsburgh; Victor Ugaz, Texas A&M; Jim Gilchrist, Lehigh University; Pam Kreeger, University of Wisconsin; Christa Hestekin, University of Arkansas; Tatiana Segura, UCLA; Chris Ellison, University of Texas at Austin; Shannon Seurynck, University of Arkansas; Rodney Priestley, Princeton University; Daniel Stouffer, University of Canterbury in New Zealand; Shannon Ciston, University of California, Berkeley; Stacey Finley, Johns Hopkins University; and Jim Pfaendtner, University of Washington.

The goal of the Teaching Apprentice Program at Northwestern University is to provide an opportunity for participants to have real responsibility, teaching a certain fraction of course material (~1/3) in a supervised setting. Frequently, we identify subsets of the syllabus for which the apprentice would be responsible that can be taught in two separate blocks of lecture time, each roughly two weeks long. This allows for feedback about the apprentice's teaching in the first block that is used to inform and improve the teaching in the second block. However, detailed scheduling is left to the discretion of the instructor and apprentice, depending on the particular needs of the course. Once the broad division of labor is established, the following points describe anticipated roles of the apprentice and the faculty mentor:

Apprentice

- *Attend the classes leading up to teaching blocks to provide continuity.*
- *Prepare and deliver lectures on the selected topics.*
- *Serve as the primary office hours resource for those portions of the class delivered.*
- *Prepare homework assignments and solutions, covering the material that apprentice is delivering.*
- *Prepare exam questions relating to the material apprentice delivers. Assist in grading examinations and assignment of grades.*

Faculty mentor

- *Attend lectures given by the apprentice. Provide constructive feedback.*
- *Check apprentice teaching plans and homework assignments for consistency with course syllabus and objectives.*
- *Work to prepare students for the experience. In particular, make it clear that apprentice should be given same respect by students and TAs as that afforded to instructor.*
- *At conclusion of first period, and at end of course, provide written evaluation of apprentice's performance, and suggestions for improvement.*

SUMMARY

Based on the experiences of the teaching fellows at these three schools, we conclude that the teaching fellowship program is an excellent experience for graduate students regardless of whether they become academics or choose industrial careers.

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APPENDIX 1. COMMENTS FROM TEACHING FELLOWS AT UNIVERSITY OF DELAWARE

Name: Henry Ashbaugh
Course Taught: Introduction to Chemical Engineering
Faculty Mentor: T.W.F. Russell

I believe the teaching experience has helped me in developing my expectations for students and how to develop a meaningful teacher/student relationship. I also have contributed two CEE *articles on my experiences during hurricane Katrina and on a teaching tool I developed for class.*

Name: Michelle O'Malley
Course Taught: Mass and Heat Transfer
Faculty Mentors: Anne Robinson, T.W.F. Russell, and Chris Roberts

Through my fellowship experience, I became much more comfortable

speaking in front of a crowd and "thinking on my feet" in response to student questioning during lecture. I also learned that a mixture of teaching styles is critical to engaging the students during class. By far, the valuable thing I learned during my time as a teaching fellow was time management—you simply cannot devote 8 hours of preparation time to one lecture. I remember struggling with this during my fellowship experience, as I wanted to have time to "rehearse" prior to teaching the lecture. Fraser encouraged me to prioritize my time in other ways, and to be open to straying from my lecture notes. As a new faculty member, this was invaluable advice, as you are responsible for so many other things when you are building a lab and mentoring graduate students/postdocs.

Name: Peter Millili

Course Taught: Chemical Process Analysis

Faculty Mentors: Norman Wagner, Burt Diemer, Ruth Sands, and Richard Grenville

My teaching fellowship covered the Senior Design class, where I had the opportunity to lecture on various plant operational topics but also mentor groups as they executed their projects. As someone who did not go into academia but rather an industrial/manufacturing setting following graduate school, (I feel) the experiences I gained teaching that semester were incredibly useful. My first assignment post-graduate school was in a vaccine manufacturing plant, providing technical support to a 24/7 operation, troubleshooting challenges that would arise. For example, a temperature measurement in a critical unit operation in one of our processes was running outside of specification. One possible root cause involved the temperature measurement device itself reporting an incorrect value. I remembered my mentors often joking about how "when in doubt, always check the measurement system first"—and, sure enough, the temperature probe was improperly installed, touching the sidewall of the piping, creating a false measurement. Professor Russell in particular used to tell me many stories (always with his unique wit included) of his ventures into the industrial world—his practical approach to problems is something I always try to emulate when faced with new challenges.

During several of my interviews, the teaching fellowship was a point very frequently picked up on by employers since it was a unique experience. The whole experience opened up many great conversation topics, which allowed me to emphasize all of the skills I had accumulated. Most importantly, employers viewed the teaching experience as good practice for communicating—which is something I have found early on in my career to be the most important skill one can possess. Being trained by the best on how to do this effectively is definitely a valuable part of my education at Delaware.

Name: Will Medlin

Course Taught: Mass and Heat Transfer

Faculty Mentors: Anne Robinson, T.W.F. Russell, and Norman Wagner

The format of the teaching fellows program allowed me to start to learn how to teach via guided practice with immediate feedback—in other words, it helped me learn how to teach the way our students learn. When I participated in the program, there were two sections of the same course that were taught in adjacent time slots. I first got to attend a section taught by Fraser, then taught my own section (which he attended). In this way, before teaching my own section I got ideas from watching him teach, and then received in-depth feedback from him after my own section.

I have received several awards. Twice I was named by the students of our department as outstanding instructor of an undergraduate class, and once as outstanding instructor of a graduate class. I have also received the top teaching award in the College of Engineering—the Hutchinson Teaching Award. Finally, I received the top award given by the university for teaching—the Boulder Faculty Assembly Excellence in Teaching Award. All the awards except the graduate instructor award were pre-tenure.

Name: Kelly Schultz

Course Taught: Mass and Heat Transfer

Faculty Mentors: Anne Robinson and T.W.F. Russell

Being able to interface with the faculty as an instructor was very valuable. I was able to learn how they prepare for classes and how they then execute their plans. I also found great value in interfacing with the students. I was given the job of telling some students that they needed to pull up their grades and even though unpleasant it was a valuable lesson in delivering bad news to students since everything isn't always so positive.

Name: Matt Helgeson

Course Taught: Mass and Heat Transfer

Faculty Mentors: Anne Robinson and Norman Wagner

Perhaps it is obvious, but the simple act of being able to get in front of students and be in the driver's seat was invaluable for numerous reasons. A key learning for me was that the mechanics of teaching are very different than the presentation style most of us learn in graduate school—audience feedback and participation are crucial, and the establishment of problem-solving concepts over specific solutions is paramount. It also gave me an appreciation for decisions regarding what material to teach and how best to teach it.

Students have commented positively on my ability to provide motivation for important concepts, and my emphasis on strategies to solving problems over detailed solutions for specific problems. One student remarked, "I didn't know I could learn so much about a problem without solving a differential equation."

Name: Wim Thielemans

Course Taught: Mass and Heat Transfer

Faculty Mentors: T.W.F. Russell and Norman Wagner

My early exposure to teaching and the ability to interact and discuss your teaching performance with more experienced faculty was most valuable. I get some of the highest student reviews in the department.

Name: Yakov Lapitsky

Course Taught: Mass and Heat Transfer

Faculty Mentors: T.W.F. Russell and Norman Wagner

Learning to develop and deliver lectures was very helpful, but the most valuable part for me was learning how to teach students problem-solving skills. To this end, I routinely use the layered problem-solving approach described in the Mass and Heat Transfer: Analysis of Mass Contactors and Heat Exchangers, *Cambridge University Press, 2008 (with some very minor modifications) in both my undergraduate and graduate transport courses. This also comes in handy in advising my research students.*

The teaching fellowship did generate some interest during my job interviews, although (at most schools where I applied) much more attention was paid to research. The biggest difference that the teaching fellowship made for me was enabling me to hit the ground running when I started as a new faculty member. Having this teaching experience made the learning curve at the new job much easier to manage.

Some student comments: "Excellent course! I was fascinated by the level of interest expressed by Dr. Lapitsky in Mass Xfer. Though the course was challenging, he did put a lot of efforts to ensure that the students had the necessary tools to enable them/us (to) excel. I strongly believe that Dr. Lapitsky has made us well equipped to be able to compete with any of our peers at other schools."

"Dr. Lapitsky did a GREAT Job this semester! I have learned so much about Chemical Engineering & I really appreciate Dr. Lapitsky's

dedication to the students & our understanding. Overall I had a very positive experience in this course. Thanks Dr. Lapitsky."

"Dr. Lapitsky was a very effective professor and I learned a lot in this class. His use of experiments and examples were very helpful."

Name: Mary (McDonald) Staehle

Course Taught: Introduction to Chemical Engineering

Faculty Mentors: Jingguang Chen and Brian Willis

I was the Russell Teaching Fellow in the spring of 2008, when I co-taught CHEG112. After graduating from Delaware in May of 2010, I started as an assistant professor of Chemical Engineering at Rowan University. Rowan is a public, predominantly undergraduate institution in Glassboro, NJ. In this position, teaching is of paramount importance, and because of my experiences at Delaware, I was ready to hit the ground running. In my first two years, I have taught eight different classes with students at all grade levels. Recently, I was honored with the 2012 Outstanding Teacher Award from the chemical engineering class of 2012.

Having prior teaching experience allowed me to walk into each new course with confidence and set a positive tone. But perhaps the most valuable thing that I learned from my teaching fellowship is how to recover from unexpected bumps in the road. Good teachers have the ability to adapt to their students, to change directions mid-lecture in order to achieve the learning objectives, and to maintain their students' attention. Unfortunately for most faculty members, these are skills that must be developed. In my teaching fellowship, I had the opportunity to make mistakes with the comfort that someone was there to help me pick up the pieces. I learned how (to) traverse the bumps in the road and move forward rather than stopping, and I found my own teaching style. I have found those to be invaluable skills in my teaching career, and I credit the UD teaching fellowship for helping me to develop those skills.

I was asked specifically about the teaching fellowship during my preliminary phone interview as well as repeatedly during my on-campus interviews. It seems as though this was something that my colleagues were interested in hearing more about and also something that helped me to get my current position. I imagine that having two of Fraser's students on the faculty led to their prior knowledge about the fellowship as well, but I definitely found it to be a positive factor in my hiring process.

I received the 2012 Outstanding Teacher Award from the Rowan Chemical Engineering Class of 2012. This is an award that is voted on by the students.

Student comments from the last two years:

"Dr. Staehle was very clear and enthusiastic about her subject."

"Dr. Staehle was very helpful and enthusiastic."

"I really enjoyed being your student. One of my favorite teachers I have ever had at Rowan. "

"Very organized"

"Very clear lectures"

"Best teacher to date"

"Great teacher"

Name: Claudio Glemi

Course Taught: Chemical Process Dynamics and Control

Faculty Mentor: Babatunde Ogunnaike

There were two aspects of the fellowship experience that have been valuable for me: (i) the opportunities to talk with Dr. Russell. At these meetings we discussed teaching and research issues, but more importantly, I had the chance to know his vision and get touched by his passion about teaching; (ii) the possibility to teach what I consider one of the hardest courses in the ChE curriculum: CHEG401 Chemical Process Dynamics and Control. Teaching this course, considering that I was a foreign graduate student (from Chile) and I was under the supervision of Dr. Ogunnaike, a world renowned and several-times-awarded instructor, was an amazing experience. Numerous times I said to myself "If I am able to teach this class in English, I will be able to teach anything to anyone in Spanish." Said and done.

Since 2007, at the Pontificia Universidad Católica de Chile I have received three teaching awards. Two Excellence Teaching Awards from the Engineering School (2008, 2010), and in 2011 I was one of the recipients of the PRED Award, the most important teaching award granted by my institution to its faculties.

The following student comments (translated from Spanish) are a sample from my Transport Phenomena class:

"Excellent course! Prof. Gelmi was always concerned about our learning, looking for different examples and ways to motivate us."

"Very engaging instructor! The best CHE course that I've taken so far!"

"I loved transport phenomena. I appreciate that Prof. Gelmi make easy a topic that is very hard!!!"

APPENDIX 2. COMMENTS FROM TEACHING FELLOWS AT UNIVERSITY OF ALBERTA

Name: Inci Ayranci

Course Taught: Process Analysis

Faculty Mentor: Suzanne Kresta

This fellowship is a great opportunity for graduate students who want to learn about teaching under the mentorship of a well-experienced faculty member.

Under the fellowship, I worked as co-instructor with chemical engineering professor Suzanne Kresta in a course on material and energy balances. The course introduces students to concepts of large-scale processing and challenges them to understand and account for all of the material and energy that goes into and comes out of a production process.

I learned a lot through the fellowship because I was able to get involved in every level and Dr. Kresta's mentorship was really important. It's nice to have that interaction with students. It makes you look at things differently and you get better at communicating your ideas with others.

The reward is seeing students pick up a new concept and work with it. Another plus is that teaching allows you to know your subject more deeply.

Courtesy of <www.industrymailout.com>

Name: Nemanja Danilovic

Course Taught: Introduction to Materials Science and Engineering

Faculty Mentor: John Nychka

John takes the mentorship very seriously. He comes to all of my lectures and we sit around for a half-hour or an hour talking about what I could have done better, improvements I could have made. We talk about upcoming lectures and we design demonstrations ahead of time.

(Sitting in on classes Nychka teaches) has been an amazing experience. This fellowship lets you teach a course with the safety net of a mentor.

I got to really experience teaching, to learn what teaching is like and what the workload is like. The best part about it is feeling this joy of teaching and educating students. You get to see students progress through the semester, and in their exams, and in the questions they ask. That's something I've always been curious about. ❐