

UW Academic Challenge and Engagement Study (UW ACES): Chemical Engineering

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INTRODUCTION

Research on learning in college shows that learning is profoundly shaped by the goals, practices, cultures, and values of the academic disciplines¹, particularly the disciplinary practices in students' majors. Therefore, if we are to understand the kinds of experiences that students find intellectually rigorous (and, thus, engaging), we need to examine challenge in the major. Understanding challenge in the major is important because at every stage of their college experience, students report that they want to be challenged, that they perform better in courses that are challenging, and that they value classes that stretch their thinking and ask them to demonstrate learning more than they value classes that ask little of them.² Although learning about where students experience challenge is important, asking students to describe challenging learning experiences in their majors requires some prior understanding of how those majors operate. The Office of Educational Assessment (OEA) designed the UW Academic Challenge and Engagement Study (UW ACES) to accommodate these needs.

METHOD

Qualitative methods are recommended when researchers are seeking to understand the complex learning experiences of students, as well as the meaning they ascribe to those experiences³; therefore, we designed the UW ACES to be primarily an interview study.⁴ Using a "citizen science" model, OEA asked departmental advisers if they would be willing to volunteer to interview seniors in their departments who came in to advising to apply for graduation. Advisers are knowledgeable about their academic programs, understand disciplinary practice in their departments, and are trusted by students in the major, so they have the best chance of gathering good information from seniors about their experiences in the major.

Sixty-six advisers from 33 undergraduate programs volunteered to participate. During the 2012-13 academic year, the volunteer advisers asked students if they would participate in brief (5-10 minute) interviews about challenge in the major. If the students agreed, advisers asked them to respond to four open-ended questions, entering students' responses directly into a Catalyst survey form that OEA researchers had designed for that purpose. The questions were as follows:

¹ Beecher & Trowler, 2001; Bransford et al., 2000; Beyer et al., 2007; Donald, 2002; Pace and Middendorf, 2004; Wineburg, 2001, 1991; Neumann et al., 2002; Shulman, 1988; Biglan, 1973.

² Beyer, et al., 2007.

³ Merriam, 2001.

⁴ One participating department, Chemical Engineering, asked students to respond to the open-ended questions in writing.

1. What do you consider to be the most challenging work that you had to complete in this major? And by "challenging" I mean doing the work that stretched your thinking the most. This can be anything—a project, a paper, an exam question, homework, something else you did related to the major.
2. What made the project/class/activity challenging?
3. What did you do or learn that enabled you to meet those challenges?
4. What do you think you learned by completing this project/class/activity?

In addition, advisers asked students in what course the challenging work took place and how many quarters they had until they graduated.

Researchers in OEA conducted training workshops in interviewing skills with all participating advisers, provided individual departments with survey customization if required, and monitored all resulting interviews, reporting back to advisers about the interviews they had conducted. By the end of the academic year, departmental advisers had interviewed 1,237 students, about 17% of the total 2012-13 graduating class. Students' responses were analyzed using a constant comparison method⁵, an inductive process designed to let themes emerge, rather than imposing assumed categories on students' comments.

STUDY LIMITATIONS

If we interviewed students post-graduation, they would be likely to identify their capstone courses or their advanced senior-level courses as the ones asking for their most challenging work. However, because we wanted to attach the interview to a time when students would normally see their academic advisers, we interviewed students when they came into the advising office to apply for graduation, which often meant that they were two or three quarters away from graduation. Senior-level courses, particularly capstone or capstone-like classes, are those which students often say are their most challenging and satisfying. Although interviewing students as they applied for graduation meant that we might not gather information about late-senior year courses, we felt that it would be interesting to departments to learn the kinds of challenges that lead to and prepare students for those more advanced experiences.

CHEMICAL ENGINEERING RESULTS

Chemical Engineering was one of the UW ACES' 33 participating departments. Because he wanted to capture the students' senior year, Dave Drischell, Academic Services Director, decided not to interview students when they applied to graduate, but instead he invited students to respond in writing to the interview questions online. Twenty-two Chemical Engineering majors responded. This number represents about 38% of the 55 seniors in Chemical Engineering who graduated during the 2012-2013 school year.⁶

⁵ Merriam, 2001.

⁶ The number of undergraduate degree completions is based on the 2012-13 UW Profiles reports published by the UW Office of Planning and Budgeting (https://bitools.uw.edu/views/13-SummaryandTrendsDegreeAttributes_0/13-Dashboard#1)

Quarters to Graduation and Where Students Experienced Challenge

Nineteen of the students who responded to the interview questions were in their final quarter and two students reported having two quarters until graduation.

Overall, the 21 students listed nine courses as presenting them with significant challenges. Five listed more than one course as the source of their greatest challenge.

Students identified two 300-level courses and seven 400-level courses as the sites of their most challenging academic experiences. The list of courses in the major as well as the number of students who identified them (only one if not otherwise noted) were as follows:

CHEM E 310: Material and Energy Balances (2)

CHEM E 330: Transport Processes I

CHEM E 436: Chemical Engineering Laboratory I (5)

CHEM E 437: Chemical Engineering Laboratory II (6)

CHEM E 480: Process Dynamics and Control

CHEM E 485: Process Design I

CHEM E 486: Process Design II (6)

CHEM E 497: Special Projects in Chemical Engineering Design

CHEM E 498: Special Topics in Chemical Engineering

The following were mentioned by one student each when asked in what course their challenging work took place:

Junior year, Fall and Winter; Senior year Fall and Winter

Senior Designs

Co-ops

1. Students' Greatest Challenges

Students were asked: "What do you consider to be the most challenging work that you had to complete in this major? And by "challenging" I mean doing the work that stretched your thinking the most. This can be anything—a project, a paper, an exam question, homework, something else you did related to the major."

One major theme, one minor theme, and various individual responses emerged from student interviews.

A class or classes. Fifteen (71%) students mentioned a specific course or group of courses when asked to explain their greatest challenges in the major. One-half of these students specifically noted that Unit Operations classes were particularly difficult with several citing the associated labs. In the words of six students:

- *I found that all the Unit Operations labs and Senior Design classes were pretty hard. Taking many classes at the same time, it is challenging to maintain good grades for all classes. These classes require so much research and critical thinking.*
- *Unit Operations I, Unit Operations II and Senior Design II were the toughest courses that I have taken in CHEM E. However, they stretched my thinking, challenged my communication skills and ability to plan, and really taught me how to work as a team player. There were definitely times that I struggled and lost motivation to work on the project, but it also brought some of my best work in the major and I'm really proud of those moments.*
- *CHEM E 437 was a very difficult class that provided limited instruction and required a lot of self-learning for the labs.*
- *Unit Operations II definitely stretched the students the farthest. I am not necessarily sure if this stretched our thinking the most, but definitely the physical limitations of our bodies and our concept of a "hard quarter."*
- *The whole Unit Operations 1 class.*
- *Transport 1 was the most challenging course.*

Senior design projects. Four (19%) students reported that the work needed to complete the senior design projects was the most challenging aspect of the major. In the words of two students:

- *The design projects for both quarters were definitely most challenging. It felt like real engineering because a lot of factors had to be taken into account and important decisions needed to be made that would affect the overall project.*
- *The optimization work on the senior design project was most challenging.*

Finally, individual students gave the following verbatim responses:

- *The biggest challenge that I had was probably switching between academic work in the classroom and working in industry during co-op experiences.*
- *I wouldn't say that there was any given project/paper/assignment/etc. that was any more challenging than any other. However, Winter Quarter (senior) was by far the most challenging thing I have ever done.*
- *Dr. Holt's homework*
- *My undergraduate research*

2. What Made Those Activities/Classes Challenging?

Next, students were asked to note what it was about the activity or the class they had described that made it especially challenging. About 29% of the students who responded to the interview questions identified more than one reason the course or project they had described was challenging. One major theme and two minor themes emerged from students' responses.

Time commitment/amount of work. Nine (38%) of the students reported that the activity or class was challenging because of the time commitment needed to complete necessary coursework. In the words of five students:

- *It was a challenge to put in the time required to do a good job. Putting in 25+ hours a week into this class alone was a very common work schedule.*
- *The time commitment was vastly immense.*
- *The work itself during winter quarter was not hard, but the amount of work that was required was overwhelming. While I am normally able to try my hardest and do my best in every class I take, during winter quarter I had to choose which classes were the most important to me because I knew I would not have the time to work on the others.*
- *The ridiculous expectations and unreasonable amount of work required*
- *It was a lot of work to balance with our busy schedules.*

Difficulty of the subject matter/techniques. Five (24%) of those responding to the interview questions commented that the work was particularly challenging because of the complexity of the subject matter and difficult techniques. For example:

- *The concepts are abstract and you deal with immensely large numbers. You have to apply basic thermodynamics to complicated and hard to define systems.*
- *The number of new considerations that had to be taken into account. Design I had a lot of short cuts, but Design II brought a lot more to the table such as Optimization techniques, Heat recovery, Physical unit construction, and new Aspen tools, among others.*
- *We also had to stretch our thinking and do a lot of outside research to understand what was going on in each Unit Operations, as well as the data we needed to collect and how we needed to run it.*

Lack of direction. Five (24%) students reported that the classes or projects were a challenge because there was little instruction offered and often they were tasked with figuring out the goals and the steps needed to reach those goals. In the words of three majors:

- *It was challenging because I was not sure how I was supposed to organize experiments.*
- *Knowing how to problem-solve was a challenge. For example, what is your objective? What information do you have and what info do you need or not need?*
- *Labs were difficult and no instruction was provided.*

Other: Two or three students each spoke of the following as aspects of the class or project that made it particularly challenging:

- **Knowledge required from previous classes (3).** *I felt that the level of chemical engineering knowledge I had prior to this class was not up to par with everybody else in the class. This made it difficult to plan the experiments.*
- **Working in a group (2).** *Working in a group of different people. Technically, we all knew (or were learning) how to do the work, so it wasn't as difficult, but working with others in the planning and execution of the projects I think was the hardest part.*

Three students each gave the following responses as to why the course/project was challenging:

- *Other than being poorly organized and a new class, it was mostly about business and marketing. It was a different way of thinking about things and required many soft skills that I didn't use much in engineering. I also had no personal interest in the class itself. It was a strategic move to make my degree plan work better. Also, I knew it would be hard and challenge me, so I took it.*
- *I'm not good at presentations and I was forced to do some.*
- *While the program does an excellent job preparing students to go on in a career in academia, I am not sure that we get the most practical education for going into industry. There seems to be a disconnect between what I learned in the classroom and what I did on the jobsite.*

3. What enabled students to meet those challenges?

The majority of students responding to the interview questions discussed a single, specific source of assistance that enabled them to meet the challenges they summarized; however, four (14%) students cited more than one source of help. Overall, students' responses produced one major theme, one minor theme, and numerous individual responses.

My own efforts. Forty-three percent of the students explained that their own efforts helped them to meet the challenges that they described. More specifically, students explained that they put in extra time and effort reading, studying, and doing additional research. Moreover, several students commented that they learned how to more effectively manage their time in order to meet the challenges in the major. In the words of six students:

- *I tried my best to re-learn things that I needed to learn.*
- *I learned to use outside research materials and manage my time better.*
- *I asked a lot of questions, and really just opened my mind to think practically about how these principles can actually be employed.*
- *Organization is important. I learned to break up the work into smaller segments and tackle them one at a time. At first it might seem daunting but once a good way to tackle it is proposed, it is not that bad.*
- *I improved my time management and initiative to learn things outside of class.*
- *I learned the new aspects, played around with them to get a feel for how they worked, and applied them to the design in a broad thinking application.*

Learning to work with others. Four (19%) participants indicated that learning how to work effectively with others was particularly helpful in meeting the challenges put forth by the major. For example:

- *Learning effective teamwork helped greatly in meeting those challenges.*
- *I learned to be polite and honest with group members. If someone is not doing his work, you need to talk to him and ask him to do more.*

Other: Two students each explained that they met the challenges in the major as a result of:

- **Help from the professor (2).** *I talked to the professor and discussed issues. It is always helpful and saves a lot of time on problems.*
- **Personal sacrifice (2).** *I had to sacrifice my personal relationships, my free time, and my mental well-being to achieve average grades in my core classes. I had to choose which classes to neglect, which unfortunately affected partners in group projects. The amount of stress I dealt with during winter quarter made my ability to study effectively and work well plummet, so I was spending all day working on projects but not getting anything done. I wouldn't say that I succeeded in meeting the challenges successfully. I simply survived them.*

Four students each gave the following verbatim responses when asked how they met the challenges in the major:

- *In my co-op experiences, while I certainly had to have the foundational knowledge I had learned, the more important aspects dealt with economics, safety, bureaucracy, and management. These topics were virtually untouched until senior year of the program.*
- *I learned process design, mass and energy balances, and computer skills.*
- *I learned that I spent way too much time getting torn apart by the completely arbitrary TA grading.*
- *I learned that quality and accuracy are secondary. It is more about how you dream and project yourself than what you can actually do. It is about what you want your product that you are designing to be and not what it is. If you get people to believe that your product will succeed, then they will help you. The learning was all trial by fire.*

4. What did students learn by completing this project/class/activity?

Three themes emerged from students' responses to the question about what they had learned by meeting the challenges they had described, along with responses that were largely unique.

Time management skills. Seven (33%) of the participants said that they learned time management skills as a result of completing the class and/or activity that posed a challenge in the major. The following quotations illustrate this category of response:

- *I learned to start work earlier rather than late.*
- *I learned how to break down bigger projects into smaller, easy steps.*
- *Good time management is important.*
- *I learned to be efficient.*

Teamwork skills. Six (29%) of the participants explained that they gained valuable teamwork skills as a result of meeting the challenges described. In the words of three of them:

- *I really liked working on these team projects because it gave us the ability to work on something larger than what we may be capable of doing alone over longer periods of time. It also allowed me to see how other people work and I learned a lot of new skills technically and socially.*

- *I learned to work with other people and communicate with others. I learned that group projects must have well-defined roles and good communication to be successful.*

Real-world engineering skills. Five (24%) participants commented that they learned real-world engineering skills and gained a better sense of what it would be like to work in industry. In their own words:

- *I learned the application of engineering design. It really came down to making this a real-world degree, moving away from theory and into application. It is refreshing as well as daunting.*
- *My co-op experience was invaluable at opening my eyes as to what chemical and process engineers do in industry. I had imagined the job to be more office/academic related, but that plays probably the smallest role.*

Other. In addition to these themes, two or three students each identified the following as things they had learned by completing the activity they had described as most challenging:

- **Content knowledge (3).** *This was a great introduction to the discipline of Chemical Engineering.*
- **Writing skills (2).** *I learned technical writing skills.*

Finally, individual students gave the following responses when asked what they learned as a result of meeting the challenges in the major:

- *I also learned that I hate Unit Operations.*
- *I learned that the human body can handle a lot but there are physical limitations to what one human can do.*
- *I learned that it is best to understand something the first time than to go back and attempt to re-learn it later.*
- *I learned how to put up with unreasonable expectations (something a future boss might do).*
- *I learned to ask questions if things need clarification.*

SUMMARY

Students in the Chemical Engineering major were most likely to identify a specific class or set of classes as the sites of their most challenging work, and, as the student example in the box that follows this summary illustrates, they often identified the Unit Operations courses and their accompanying labs as specific sites of challenge. Several students also mentioned that the Senior Design Projects were a particularly challenging aspect of the major, especially given the real-world nature of the projects. In the words of one respondent:

The design projects for both quarters were definitely most challenging. It felt like real engineering because a lot of factors had to be taken into account and important decisions needed to be made that would affect the overall project.

Students explained that courses and/or projects were challenging because of the time commitment required to complete course requirements. Moreover, students cited the complex subject matter and difficult techniques (e.g., optimization techniques) as reasons why the courses and/or projects were a challenge. Several students noted that labs were particularly difficult because they were required to proceed independently.

When asked what helped them meet the challenges they had described, students were most likely to cite their own efforts, which broadly included putting in extra hours studying, reading, and completing outside research. Among other efforts, students added that they met the challenges by learning how to manage their time more effectively. One participant explained:

Organization is important. I learned to break up the work into smaller segments and tackle them one at a time. At first it might seem daunting but once a good way to tackle it is proposed, it is not that bad.

Students also commonly noted the value of working with peers, particularly on projects with a shared goal, to meet the challenges posed by the major.

When asked what they learned by completing the project/class, students were most likely to mention that they learned how to both manage their time more effectively and how to work together with other students to effectively complete a complex project. Furthermore, respondents wrote that they gained a greater understanding of what it would be like to work in industry including how to apply engineering design principles.

In sum, although the number of students who responded to the interview questions was fairly small, the students' responses are reflective of the broad goals of the Chemical Engineering major, which aims to provide students with a command of challenging subject matter, effective problem-solving skills, and the dedication to pursue employment in industry or graduate study.

In closing, students' responses to the UW ACES interview questions suggest that Chemical Engineering majors felt that the challenges they described were inherently rewarding. As one participant commented:

There were definitely times that I struggled and lost motivation to work on the project, but it also brought some of my best work in the major and I'm really proud of those moments.

These positive responses to being intellectually challenged are consistent with research on student learning, which shows that when an assignment is challenging for students and when instructors help students meet those challenges, students are engaged in their courses and, therefore, learn more than when coursework is easy.

One Student's Responses to All Four Questions

Course where greatest challenges occurred: Unit Operations Labs and Senior Designs

Q1. What was the most challenging work you did? *I found that all the Unit Operations labs and Senior Design classes were pretty hard. Taking many classes at the same time, it is challenging to maintain good grades for all classes. These classes require so much research and critical thinking.*

Q2. Why was it challenging? *There is no right answer to anything. You need to do a lot of research and decide what information to use and what not to. It is also hard for group members to work at the same level.*

Q3. What helped you meet that challenge? *I learned to be polite and honest with group members. If someone is not doing his work, you need to talk to him and ask him to do more. I talked to the professor and discussed issues. It is always helpful and saves a lot of time on problems.*

Q4. What did you learn by meeting that challenge? *I learned to be efficient, work with other people, and communicate with others.*

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