

UW Academic Challenge and Engagement Study (UW ACES):

Biology

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March 2015

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 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. 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.

BIOLOGY DEPARTMENT RESULTS

The Biology Department was one of the UW ACES' 33 participating departments. Janet Germeraad, Andrea Pardo, and Jason Patterson asked 69 students in the major if they were willing to be interviewed for the study, and all of them agreed. This number represents about 11% of the 632 seniors in Biology who graduated during the 2012-2013 school year.⁶

In order to investigate differences among areas of concentration in the major, we asked students which area they were specializing in. No students specializing in Plant Biology were interviewed, and three of the interviewees (4%) did not specify their academic tracks in the major. The remaining 66 students were arrayed across the major tracks in the Biology major as follows:

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://uwprofiles.uw.edu/Viz/View/13-SummaryandTrendsDegreeAttributes>)

- Ecology, Evolution, and Conservation Biology (EEC): 5 students (7% of the Biology interviewees)
- General Biology (GB): 28 students (41%)
- Molecular, Cellular, and Development Biology (MCD): 16 students (23%)
- Physiology: 17 students (25%)

As we report results, we identify differences, if any, in the responses of students in particular tracks in the major.

Quarters to Graduation and Where Students Experienced Challenge

In terms of time to graduation, the majority of interviewees (about 52%) had two quarters left before graduating. About 39% had three quarters left. Four students (6%) were completing their last quarter before graduating and two (3%) students had four quarters left before they graduated.

When asked which courses in the major had presented them with the greatest challenges, students listed a total of 47 classes in Biology and related areas, along with four other kinds of responses about their experience in the major. Among the courses students listed as presenting their most significant challenges, 53% were in the Biology department, itself, with about 60% of those Biology courses at the 400-level. The course most frequently mentioned was Biology 350, noted by 11 (16%) of the 69 interviewees as presenting them with their most significant challenges in the major. Eight of these students were in the Physiology track, and three were in other tracks.

In addition to Biology courses, 13% of the courses students listed were Chemistry classes, and the remaining courses were primarily in disciplines related to Biology, as the list that follows shows.

Biology . Twenty-five courses were Biology courses. The list below identifies the course and the number of students mentioning that course (if more than one).

BIOL 180 (3)	BIOL 404 (mentioning Dr. De La Iglesia)
BIOL 200	BIOL 405
BIOL 220 (4, one mentioning Dr. Zeman)	BIOL 411 (2)
BIOL 302	BIOL 413
BIOL 305	BIOL 425 (2)
BIOL 325	BIOL 443
BIOL 340	BIOL 454
BIOL 350 (11, four mentioning Dr. Wenderoth)	BIOL 455
BIOL 355 (6, two mentioning Dr. Parrish)	BIOL 468
BIOL 380	BIOL 471
BIOL 400	BIOL 479
BIOL 403	BIOL 481
	BIOL 499

Biochemistry. Three biochemistry classes were listed, as follows:

BIOCHEM 405 (5)	BIOCHEM 440
BIOCHEM 406 (3)	

Chemistry. Students listed nine chemistry courses when asked in which courses their greatest challenges occurred:

CHEM 142 (2)	CHEM 237 (2)
HEM 152 (2)	CHEM 238 (4)
CHEM 162 (2)	CHEM 239 (2)
CHEM 223	OCHEM (2)
CHEM 224	

Genome. Four students identified two courses in this area, as follows:

Genome 361 (2)	Genome 371 (2)
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Other Courses. Students mentioned eight additional courses:

MATH 124	PHYS 115
MATH 125PATH 499	PHYS 116
PHARM 499	POL SCI 384
PHYS 114	

Other experiences. Finally, when asked to note the courses in which their significant challenges occurred, several students said the following:

Upper division Biology courses (2)	Independent study/abroad
All courses (3)	No class—figuring out what to do with degree for the future
Overall experience	

The spread of courses in the major suggests that students experienced challenges across the Biology curriculum. Furthermore, that so many 400-level Biology courses were mentioned by a group that included many students who were one quarter into their senior years indicates that students in the major do not move through the major sequentially.

Differences in areas of concentration. Students in the four Biology areas of concentration that we were able to track primarily identified Biology courses as their most challenging, followed by chemistry; however, there were some differences in the areas as follows:

- **EEC.** The five students in the EEC concentration identified two biology, two chemistry, and two other courses as the sites of their most challenging work.
- **General Biology.** The 28 General Biology students mentioned 14 Biology courses and seven Chemistry courses (five of them in organic Chemistry, as well as a general “OChem” mention), along with a few Genome and Biochemistry courses. Students in General Biology also noted that “all courses,” their “upper division Biology courses,” and their “overall experience” presented them with their greatest challenges.
- **MCD.** Students (16) in the MCD concentration mentioned 10 Biology, four Chemistry, and three Biochemistry courses, along with two math classes as the sites of their most significant challenges. One student noted that “all my upper division courses in Biology” had presented challenges.

- **Physiology.** Eight of the 17 students in the Physiology concentration identified Biology 350 as the site of their most challenging work, along with two other courses in Biology. In addition, physiology students reported Biochemistry, organic Chemistry, Pathology and Pharmacology courses as the sites of their greatest academic challenges, with one student noting that all of the courses in the major had been challenging.

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."*

About 26% of the interviewees gave more than one response to this question. Two strong themes and several minor themes emerged from their responses.

A course. Most of the students (62%) mentioned a whole course or courses as representing their most challenging work in the major, including students in all four areas of concentration in the major we could track. The following examples illustrate this category of response:

- *Biology 380. It was really cool—policy and a combination of science and politics. I hadn't been trained in that manner before.*
- *Biochemistry was by far the most difficult course.*
- *Chemistry. The first class started as a prep class, and the material [kept building]. Flail in one, flail in all of them as a series.*
- *Honestly, I think the Biology 220 I took in the summer with Dr. Zeman, because her strategy was to give us problems—not just yes or no answers, but you had to think and apply knowledge using Chemistry, Physics, and Biology. I was watching YouTube, taking books from the medical library, and the exams were so hard, I was surprised.*
- *Biology 355. It was very in-depth and really took me beyond Biology 200.*
- *Biology 411 because it was conceptual.*
- *Biology 404, Animal Physiology. Community college did not prepare me well for this course.*
- *I would say Mary Pat Wenderoth's class, Biology 350. Just the way that she directed our attention to the material—that stretched my thinking in a way that other classes had not*
- *Biology 350. [The professor's] application of the subject matter made it more useful, and it stays within the memory well past the end of the class. It was a different way of thinking, the use of logic*

The exams. About 17% of the interviewees mentioned the challenge of exams. Interviewees who identified exams as especially challenging came from all areas of concentration except EEC.

- *The Biochemistry 405/406 multiple choice exams were way challenging.*
- *The Biology 180 exam, due to the structure of the exam. The nature of it was that it was more open-ended and harder to study for.*
- *In Biology 350, the general outlook, was not on recalling but on synthesis. This was not expected. On a test, we had to figure out something new, rather than regurgitate [course material]. The process of learning [was important], especially by the end of the class on the final. This was applicable to other classes.*
- *Exams were synthesis based, which was new.*
- *In Chemistry 142, test timing and management. It was a big adjustment from high school—a different style, faster and more demanding in quantity.*
- *In Biochemistry 405, the huge class size affected learning. There were three exams with multiple choice questions. The multiple choice exams limited my ability to think.*

Writing scientific papers and lab reports. A third theme in students' responses to this question—mentioned by 10% of those interviewed—was writing in the discipline. Students who reported writing papers and lab reports as their greatest challenges came from all of the areas of concentration we tracked. The following examples illustrate this category of response:

- *In Biology 340, I had to write a paper. It included extensive peer review and spanned the entire quarter. It was my first time writing a scientific paper.*
- *Writing scientific papers.*
- *I would say that formulating proposals and papers for my honors research has been the most challenging because there's not a lot of that in the courses.*

Projects. Five (7%) of the interviewees noted projects as their most challenging work in the major. For example:

- *In Biology 305, we had an end video project, taking some scientific stuff and applying it in a new direction. We had to water down the information to make it applicable for non-science people.*
- *In Biology 340, we did a DNA project using genome sequencing that used a phylogenetic tree to find where seahorses were found in the world.*
- *I did an independent project in Africa. I took notes on triage days and the living conditions. I tried to find correlations between living conditions and symptoms to find ways to improve it. The challenge was determining what to do with it after compiling it.*

Reading and understanding the scientific literature. Another minor theme, mentioned by 4 (6%) of the interviewees as their greatest challenge in the major, was reading and understanding the scientific literature. In the words of three of these students:

- *In Biology 325, we were first made to absorb and integrate scientific literature into information that our classmates could understand.*

- *Biology 350 was the first class that exposed us to reading scientific works, reading and interpreting graphs in a paper. I had no experience with that and was unsure about the standards and expectations.*
- *In Biology 355, reading experiments and breaking down the various parts. It was a different way of thinking, and I felt dumb but worked together with a group in order to get the answers.*

Other. Two or three students identified the following as their most challenging work in the major:

- Having to think in new/scientific ways (3)
- Doing real science (2)
- Specific subject areas (2, noting Chemistry and Physics courses)

In addition, individual students reported the following challenges:

- Giving presentations
- Figuring out how to apply the degree to a future career
- Getting into the classes the student needed
- Finding the personal motivation to do it all
- The gaps between the chemistry lectures and the labs
- Unhelpful teachers in chemistry
- Too much work for the time to do it
- Collaboration in labs
- Class size
- Lab work

Differences in areas of concentration. We noted a few differences in the responses of students in the four areas of focus we tracked, as follows:

- **EEC.** Two of the five EEC students identified projects as their greatest challenge in the major.
- **General Biology.** Students in the General Biology track primarily identified a class (50%), exams, or writing as the most significant challenges in the major.
- **MCD.** Fifteen out of the 16 students the MCD track mentioned a course as their greatest challenge in the major and close to a third of those students also mentioned exams as challenging.
- **Physiology.** Twelve (71%) of the 17 students in Physiology mentioned a course as their most significant challenge and two thirds of those students identified Biology 350 as that course. Two students noted that exams were especially challenging.

2. What Made Those Activities/Classes Challenging?

When asked what had made those activities challenging, about 14% of the 69 interviewees identified more than one challenge. Three strong themes and several minor themes emerged from students' responses to this question.

Thinking critically and analytically/having deep understanding of reading, problems, content. Close to a third of the interviewees (32%) said that thinking critically about materials and understanding them deeply enough to analyze and apply them was what made the challenges they had described particularly challenging. Several of these students noted that they needed to be able to have this critical understanding in order to come up with an argument, research question, or experiment. Students who had identified whole classes, writing, or other specific tasks such as exams as their greatest challenges in the major gave this response, so critical thinking as a challenge appeared to cross tasks and courses in the major. In the words of four of these students:

- *[I wrote a] research paper on how the rainforests are being destroyed. I had to research who was doing the destruction and why the government was allowing it. The question didn't have a concise argument so I had to delve in and make connections to correlate and read beyond the stated facts.*
- *In Biology 479, I had an integrative experience. I developed a sub-project in a professor/grad student's experiment. [It was my] first introduction to real science rather than following directions. It was my first time to look at academic literature, to go look and do something that hasn't been done before. It was overwhelming but it has made Biology 400 and 475 easier to do.*
- *In Biology 350, [a focus on application]. Prior to this, many classes were memorization-based, rather than application.*
- *In Biology 355, reading experiments, and breaking down the various parts. It's a different way of thinking.*

Understanding an unfamiliar or complex subject. Sixteen percent of the students spoke of the challenge of understanding topics that were new or complex. Students spoke about this as a challenge in their courses in general, as well as in writing and test-taking. For example:

- *Biology 380. It was really cool. It focused on policy and was a combination of science and politics. I hadn't been trained in that manner before.*
- *I'm not used to dealing with plants.*
- *I had never taken a deep look at molecules. The material was new. How are function and structure related?*
- *Organic Chemistry. I couldn't grasp the concepts, and I didn't know how to study.*

Amount of information and time needed to learn the material. About 13% of the interviewees said that the course or activity they described was challenging because of the amount of information they had to cover and/or the amount of time it took to learn the information. All of the Biology subgroups were represented in this category of response, except EEC majors, and the majority of interviewees were describing challenges posed by courses they had described. A few examples:

- *The amount of information presented compared with other courses [made it challenging]. It was, like, double the amount.*
- *The professor assumed I knew things I did not. I had to spend a lot of time in review to stay caught up.*

- *Both [courses] were high in quantity of information to grasp.*

Other. In addition to these themes, two or three students mentioned the following as presenting particular challenges:

- The large class sizes (3, two of them MCD majors). *“Format of the test and size of the class for BioChem. The constant switching of teachers here was also hard.”*
- The amount of memorization required for exams (3, all Physiology majors). *“An incredible amount of memorization, competition and time involved.”*
- The mismatch between the professor’s teaching style and the student’s learning style (3). *“It would have been nice in physics if they had a different professor teach it. I had the same professor every quarter, and i just didn’t feel like his teaching and my learning matched up.”*
- The different testing styles of the faculty (3). *“It was really difficult to gauge the different testing styles. Some faculty are really good at test questions others are not. Some write them as if they are testing faculty. The intro series was all over the map.”*
- Exams asked for too much work in too short time (2)
- Writing scientific papers/reports (2) *“Big shift to write in this style and not much support to learn it.”*
- The math/computer modeling portion of the class (2)
- The tough grading system in the class (2)
- The competitive/hostile environment of peers in the Chemistry classes (2)
- Not enough help was given (2). *“Not enough help offered to gain a good understanding.”*
- Figuring out how to use the information gathered for a piece of writing (2) *“The challenge was determining what to do with [the information] after compiling it.”*

Finally, individual students gave the following responses:

- Coming up with an interactive tool for a presentation
- Figuring out a career direction for the major besides graduate school
- Translating science into understandable information for non-scientists
- Integrating scientific literature into information that classmates could understand
- Delayed the process of completing the major
- Labs seemed like high school work
- In the exams, if you mess up on one part, you mess up the whole series of questions
- Growing a plant
- Learning new ways to study
- Good collaboration requires everyone to understand and follow instructions
- The switching of teachers in a single class
- Level of skill/techniques needed to complete labs

Exams and writing. Because students frequently mentioned that exams and writing were challenging experiences in the major, we tracked what students said about what made them challenging. Responses

that specifically addressed exams and written work were quite similar to those about courses. The challenges that students mentioned concerning exams were as follows:

- The math portion of exams
- Needing to think critically about and fully understand the material
- The unfamiliarity of the material
- The large class size
- The amount of information tested
- The length of the exam in relation to the time available to complete it
- Open-ended questions
- Frequent switching of teachers
- The different testing styles of faculty
- The amount of memorization required
- Making mistakes in one question in the exam meant making mistakes in subsequent questions

The challenges in writing were as follows:

- Needing to think critically about and fully understand the material
- Writing *scientific* papers and reports
- The unfamiliarity of the material
- Figuring out how to use information gathered for a piece of writing.

Differences in areas of concentration. There were differences in the challenges that students in the specific areas of concentration mentioned, as follows:

- **Ecology, Evolution, and Conservation.** The challenges mentioned by students concentrating in EEC were spread across those mentioned by other students.
- **General Biology.** The majority of students in the General Biology mentioned critical thinking, unfamiliar or complex subjects, and studying for exams as special challenges in the activities they noted. About 21% of the students in the General Biology concentration were speaking of challenges in Chemistry classes.
- **Molecular, Cellular, and Development Biology.** More than a third of the students in the MCD concentration identified the amount of information and time needed to learn the material as being particularly challenging aspects of the activities they described. One out of four of them identified challenges in critical thinking, and about one out of four of them described challenges in Chemistry courses.
- **Physiology.** The majority of students concentrating in Physiology mentioned critical and analytical thinking as the aspect of their activities that made them especially challenging. In addition, several students also noted challenges in understanding an unfamiliar or complex subject and in the amount they needed to memorize for exams.

3. What enabled students to meet those challenges?

A third of the interviewees identified more than one source of help for meeting the challenges they described. Three strong themes and several minor themes emerged from students' responses.

My own efforts. More than half (54%) of the interviewees credited their own efforts with helping them meet the challenges they had described. They spoke of seeking outside sources of information to bolster what they were learning in class, using CLUE or other study centers, going over their notes, and carefully managing time. About one in five (22%) of these students spoke of learning or devising a new way to study, such as building frames for learning or thinking about the whole system rather than its individual parts. The following are examples of this category of response:

- *Lots of different things [helped]—seeking help from CLUE and that stuff. I bought OChem for Dummies, which probably saved my life in that class.*
- *Studied more, went over notes.*
- *I spent time preparing for [the Chemistry] labs. Without the background ever being connected in lecture and the lack of clarity in the manual and prelabs, we would need to research unassigned chapters of the books and areas of the lab manuals to understand the Chemistry sequencing.*
- *I learned different tactics of studying—not just reading the text book.*
- *Another thing that made it challenging was that there was not always a theme, context, or frame, so we would build those frames ourselves to help us learn.*
- *I had to become more disciplined as a student and work the information backwards and forwards.*
- *I had to put in the time immediately after class. It made it smooth, putting it off at all didn't allow for learning. It wasn't just memorizing; it was applying.*
- *Taking the initiative, to look into things more than what was assigned for the class. Apply the knowledge and see how it can be applied in multiple ways, altering variables to understand ramifications*
- *Learning how to review on my own by review of course lectures. Managing my time to put into it.*
- *Think like a researcher—thinking backwards and forwards.*

Working with peers and study groups. About 28% of the interviewees reported that working with their fellow students helped them meet the challenges they had described. In the words of some of these students:

- *Finding a study buddy to talk it through with. We spent a lot of time together. It was a mini-lesson in good collaboration.*
- *I had a friend in the courses who I studied with every Sunday. We went over the material, talked to each other, sat through lectures together.*
- *Study groups. It really helps to work it out with peers.*
- *A lot of preparation beforehand. I had to adjust to no outside help or handholding and take control of my own education. I learned that a little late in the process of the course. Camaraderie with peers helped in clarifying information but happened a little late to impact or assist in my final grade.*

- *I took the course with people I knew to form study groups.*
- *Being able to freely discuss [with peers] without feeling overly vulnerable or not smart.*
- *Group study and catching each other's omissions.*

Getting help from faculty, TAs, and other graduate students. The third major theme to emerge from students' responses to the question of what helped them meet the challenges they had described was the help of faculty, TAs, and other graduate students. About 23% of the students interviewed said that their professors, TAs, and other graduate students had given them assistance in office hours, classes, and labs. For example:

- *I met with the professor and went over exams, which was good.*
- *I talked to TAs, fellow students, and faculty and had them review my work and give me feedback.*
- *Dedication and harassing the TA for help every day.*
- *Office hours. Speaking to the professor about the format helped, [and it helped] to step back and work through the process, to understand how to think through the process of learning and understanding.*
- *I found my professor was really willing to help me.*
- *Meeting with professor about how to approach this way of learning.*

Other. In addition to these themes, two or three of the Biology majors interviewed noted the following as helping them meet the challenges they had described:

- Learning to read scientific research (3). *"I had to read and understand articles or journals rather than look on Wikipedia. There was less memorization—it was synthesis instead of flash cards."*
- The class itself (3). *"I learned in the course how to pursue the insects that were needed for collection."*
- I did not meet the challenges presented (2). *"I did not engage myself to meet the challenges."*

In addition, individual students identified the following as helping them meet challenges:

- Met with advisers (from the student who said the most significant challenge she faced was figuring out a career direction for the major besides graduate school)
- Volunteer work
- Learned how to research
- Applied what I had learned in previous courses
- Learned to "tone down the science and make sure the impact was clear" (for a general audience)
- Learned that perspective matters
- The steps in how to approach research papers
- Knowing how to communicate (in working with lab partners)
- Used scientific papers as models for my own work
- Dropped and retook the class

- To use tests as a learning tool

Differences in areas of concentration. There were no patterns of response to this question in one area of concentration or another in the major.

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

We asked students what they felt they had learned by meeting the challenges they had described, and about 23% of the 69 interviewees mentioned more than one lesson learned. Several themes emerged from their responses.

Learned new ways to learn/study. The most frequently-given response, mentioned by 27 (39%) of the interviewees, was that students had learned new ways to learn Biology (and in three cases, Chemistry) as a result of meeting the challenges they had described. They mentioned a variety of approaches to learning, including prioritizing rather than simply memorizing, working in groups, asking questions of themselves and faculty, realizing that they could learn from others, and taking a systems approach to learning. Students from all areas of concentration were represented in this group of responses. The following examples illustrate this theme:

- *[In that Chemistry course] I guess just strategies for how to learn in environments that aren't ideal.*
- *Learning the perspectives of others makes it fun, and you can learn from your mistakes and readjust course plans based on the conversations.*
- *I had to learn to ask for help from classmates and anyone I could find.*
- *[I learned] a different approach to how I learn and how I try and problem solve. I think I've carried that with me to other courses.*
- *More effective strategies for studying and a new way of looking at science. Just because something isn't wrong, doesn't make it right.*
- *[I learned] not to be afraid to speak to professors, use class resources, and study groups*

Learned how to think critically and scientifically. A second strong theme that emerged from 26% of the students' responses to the question about what they learned from meeting the challenge they described was that they learned how to think critically and scientifically. Students' responses included learning to look at things from multiple perspectives, apply scientific theories to real-world issues, troubleshoot problems in experiments, and adapt learning when looking at living systems. For example:

- *How society works, how we integrate biology into law, and a good overview of the health system.*
- *Using a reverse process, look back and see how changes could alter a graph with alterations in a variable. I have applied this to other classes. This knowledge allowed for a deeper understanding of how to understand, rather than just memorize.*
- *In preparation for future situations, how to analyze situations in a new way.*
- *The class taught how to think as a scientist, hypothesize, and take steps to prove something.*

- *It's reality. It's what you do in the world, so you have to know what you are doing and how to apply it in different situations.*
- *[I learned] a new way of thinking—logic based—and a better way of studying.*

Learned something about myself. Eleven interviewees (16%) said that they had learned something about themselves by meeting the challenge they described, such as learning that “I know stuff!”, that personal effort matters, that they are not going to be good at everything, and that they have become self-confident and resourceful. Three of the 11 students in this group were speaking of Chemistry courses. In the words of four students:

- *I'm a little smarter than I think I am. I ended up doing pretty okay, so I learned to have a little more faith in myself. I have always been a straight-A student, so to learn not to look at the grade and learn that I got through it all [have] changed my perspective a little bit.*
- *I need to take more personal responsibility. Maybe it was not the right time for me to go to school.*
- *Personal effort makes a big difference in your personal outcome.*
- *Persistence is what I learned. It's not going to go away. Even if I say I don't want to do it or study it, I still have to do it.*

Learned better time management. Twelve percent of the interviewees described learning time management skills as a result of meeting the challenges they had described. As two of them put it:

- *How to make study and reading schedules.*
- *Perfected time management and working with other people and to collaborate.*

Gained a deep understanding of course content. About 7% of the students mentioned specific course content when asked what they had learned as a result of the challenges they had met. For example:

- *[I learned] a ton about insects.*
- *Better understanding of a whole system than just the parts.*

How to read, understand, or evaluate scientific articles. About 6% of the students noted that they had learned how to read articles in the field. For example:

Definitely, I know how to critically read a scientific paper, from the purpose and how important the graphs may or may not be by looking at primary data.

Other. Two or three students noted that they had learned the following:

- Learned to write scientific papers (3). *“[I learned] scientific writing skill and how to adapt and communicate in different ways.”*
- Learned more about the field and/or careers in Biology (2). *“[I learned] what it took to become that particular profession, whether it was a good fit, the lifestyle that the career demanded.”*
- The importance of having the big picture/context of what you are studying (2). *“Learned to see the big picture and apply the details. I had to learn to find the context of things.”*

In addition to these themes, individual students responded to the question by noting that they had learned:

- Nothing (about a Physics class)
- How to present scientific information to a general audience
- That you need to just do the work
- Lab skills
- The relationship of Chemistry to Biology
- To be more careful in selecting courses

Differences in areas of concentration. There were differences in the learning that students in the specific areas of concentration reported, as follows:

Ecology, Evolution, and Conservation. The learning mentioned by students concentrating in EEC were spread across those mentioned by other students.

General Biology. Students in the GB concentration primarily mentioned learning new ways to learn/study, learning about themselves, learning to think critically and scientifically, and time management skills as major areas of learning from meeting the challenges in the activities they noted. About one in five of these students were speaking about learning from challenges posed in Chemistry courses.

Molecular, Cellular, and Development Biology. More than half of the students in the MCD concentration identified new ways to learn/study as what they learned by meeting the challenges they described. Four (25%) of the students in this group were speaking of what they had learned from challenges in Chemistry courses, but only one of these students spoke of learning new ways to learn.

Physiology. Fifty-nine percent of the students concentrating in physiology said that they had learned a new way to learn or study from the challenges they had met. Close to 30% also noted learning to think critically and scientifically as a result of their challenging work.

SUMMARY

A strong theme that crossed students' responses to all questions was the challenge of learning to think critically and scientifically about unfamiliar material. A second strong theme was the companion challenge of learning to think and study in new ways—ways that emphasized analysis, evaluation, and synthesis, rather than simply memorization. These two themes operating together suggest that, although Biology is a subject all of the students interviewed most likely took in high school, the study of Biology at UW is notably different from what students practiced in high school. The heart of that difference was the kinds of thinking students were asked to develop and use in Biology here. As one student said:

We were forced to learn and think. We had to understand and synthesize not just regurgitate. It was a different style of teaching than others, and after taking [this] class, other classes were made easier. These teaching strategies translated over and made those classes easier to understand.

The strength of these two themes suggests that it would be useful for Biology students to understand these expectations early in the program—to know that they will not only be asked to learn a body of

material but to think about, analyze, and apply that material in exams, writing, discussion, and other kinds of activities.

When asked where they had experienced their greatest challenges, about 53% of the Biology majors identified Biology courses, with 16% of the interviewees identifying Biology 350 as the site of their greatest academic challenges. That close to half of the courses that students mentioned as sites of their most challenging academic experiences fell outside the major is unusual; however, most of the courses mentioned were required by or related to the major. About 13% of the courses students listed as their most challenging experiences were Chemistry courses.

In describing their most significant challenges in the major, interviewees most often mentioned a whole course (or course series in a few cases), along with challenges in taking exams and in writing papers and lab reports for the major.

As noted previously, when asked what aspects of the work they had described made it challenging, close to a third of the interviewees said that thinking critically and analytically about scientific reading, problems, or content were their greatest challenges. In addition, students mentioned understanding unfamiliar or complex subjects and the amount of information and time needed to learn material. Students also spoke of these challenges in terms of general learning and related to exams.

Students credited their own efforts, the help of peers, and the assistance of faculty and TAs as helping them meet the challenges they described. Interestingly, when speaking about their own efforts, students frequently noted that they had developed new ways to study, which helped them meet the challenges. These new ways to study, also as noted previously, were often described as applying critical and analytical thinking to course material. Students had so many good things to say about learning from peers, it is likely the Biology program is fostering such interaction and should continue to explicitly encourage students to work together.

In terms of what they thought they had learned by meeting the challenges they described, students primarily noted that they had learned new ways to think and study and how to think critically and scientifically, as the student examples in the box which follows this summary illustrate. In addition, many students reported learning something about themselves, about time management, and about specific course content, along with writing, lab, and reading skills.

As the students' comments in the box that follows this summary illustrate, the interviews clearly showed that the Biology major is asking students to think and study in new ways about topics that are also new to them. Further, students are using the kinds of learning taught as a way to study and learn course content. Results suggest that being in the Biology major expands students' sense of what the discipline is and makes clear that students' roles as learners in the field need to be active, rather than passive, which is often a surprise to students.

Finally, students' responses to the UW ACES interview questions suggest that Biology majors felt that the challenges they described in their Biology and related courses⁷ were rewarding. Indeed, many students spoke of how much they enjoyed the course or the challenging activity they described. This response to challenge is 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.

⁷ In general, students appeared to be somewhat less positive about challenges experienced in Chemistry courses.

Two Students' Responses to All Four Questions

Course where greatest challenges occurred: All my upper division courses in Biology.

Q1. What was the most challenging work you did? *In Biochemistry 405/406, it was hard covering all topics, and Biology 325 really challenged my writing.*

Q2. Why was it challenging? *Taking in information and finding some way to put it all together.*

Q3. What helped you meet that challenge? *I had to become more disciplined as a student, working the information backwards and forwards.*

Q4. What did you learn by meeting that challenge? *Learning to see the big pictures and apply the details. I had to learn to find the context of things. I had to take the time to be fascinated by the topic and then learn the details.*

Course where greatest challenges occurred: Biology 350

Q1. What was the most challenging work you did? *I think that Biology 350 was the hardest for me, because it was the first step beyond the intro series, and I was getting used to having to really understand things.*

Q2. Why was it challenging? *I think I didn't know how to study biology. I was just kind of used to doing it one way, and I had to do it another way.*

Q3. What helped you meet that challenge? *I had to read and understand articles or journals rather than look on Wikipedia. There was less memorization—it was synthesis instead of flash cards.*

Q4. What did you learn by meeting that challenge? *I think I just learned I needed to put more effort in to it, because my grade wasn't that good. I needed to get better at learning.*

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