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Commentary

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Encouraging Disadvantaged Students in Chemistry: Four-Part Harmony (or Disharmony)

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ABSTRACT: No single factor insures student success in an undergraduate chemistry course. Rather, success involves a complex interplay of the faculty, the students, the curriculum, and the campus climate. When all four "harmonize" to encourage learning, the resulting "melody" brings joy to all who hear it. However, when one player strikes a discord, students suffer and the disharmony is heard through the wider community. This paper, drawn from an awards address at the 2015 ACS National Meeting in Denver, weaves together stories of harmony and disharmony, ones that can help us to better work together to minimize the discords for all involved.

KEYWORDS: *General Public, Minorities in Chemistry, Women in Chemistry, Curriculum, Student-Centered Learning, Professional Development*

FEATURE: Award Address

Harmony. "An orderly or pleasing combination of elements in a whole."[1]

Orderly or pleasing. No doubt, a choral group perfectly fits the bill, with the voice of each singer beautifully harmonizing with those of others. Greater than the sum of the parts, music has the power to bring a smile and lift the soul. Teaching and learning have this same power.

Harmony. "I'd like to teach, the world to sing, in perfect harmony."[2]

In the 1970s, a song with these lyrics soared to the top of the charts. In part, its appeal stemmed from the world of disharmony in which people were living. As examples, think back to the Iron Curtain, hallucinogenic drugs, atomic testing, war protests, and Rachel Carson's release of *Silent Spring*.

For those of us in the classroom, it would be hard to conceive of a more uplifting mission than to teach our students to sing the songs of chemistry in perfect harmony. In the 1970s, I was among those yearning for harmony. So were my students. They came to campus each fall with their hopes, fears, and dreams, enrolling by the thousands in our general chemistry courses. Many studied chemistry because it provided a gateway to a career of their dreams in pharmacy, medicine, or nursing. A smaller number were striving to become chemists or chemistry teachers.

To pave a pathway to these dreams, administrators and/or faculty members set up "special programs" to mentor and academically assist students who were historically underrepresented in chemistry.[3,4] One such program at the University of Wisconsin—Madison was the Chemistry Tutorial Program for Minority/Disadvantaged Students, now known as the Chemistry Learning Center. In 1976, this program was founded by Marion O'Leary and launched by Elizabeth Kean, both speakers in this symposium. Back then, Minority/Disadvantaged or M/D was the term used in the State of Wisconsin to include students of color and economically disadvantaged students. Both Anthony Jacob and Derrick Arnelle, also speakers in this symposium, have a deep knowledge of M/D student success (and failure) at the Chemistry Learning Center.

I still am in touch with some of the students from the early years of the Chemistry Learning Center, and I wish to speak about one particular woman. Now over three decades later, I cannot recall either her name or her face. But I do remember the tone of her voice. One afternoon, after I had been helping her with what seemed like an endless string of equilibrium problems, she slammed down her pencil and aimed a question squarely at me. "WHAT does this buffer problem have to do with my life?" Her voice conveyed it all. She had reached a point of utter frustration, finding no meaning in her seemingly pointless toil.

As far as I was concerned, she asked precisely the right question. Yet people label this student and ones like her as "disadvantaged". Yes, she was disadvantaged in the sense that she was poorly prepared to take a college chemistry course. Yes, she was disadvantaged in that she grew up in a low-income neighborhood of Chicago. And yes, she was disadvantaged in the sense that the playing field in her chemistry course was not level; some students clearly were better able to play on it than others. But she was far more than "disadvantaged". She was smart, expressive, and determined.

She also was my teacher. This student and others like her inspired, cajoled, and perhaps even shamed me into taking steps on the path toward harmony. I could not simply label her as disadvantaged and then proceed to fix her. Rather, through her experiences I was able to see the dysfunction in the larger system in which she was learning chemistry.

In coming to recognize this dysfunction, I joined a group of singers that at first felt more like a secret club. The group was small but grew steadily in number and in strength over the years. Although the voices were different, all were singing the same tune: Our chemistry students deserve better.

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One such voice was Alexander Johnstone, the 2009 winner of the American Chemical Society Award for Achievement in Research for the Teaching and Learning of Chemistry. His awards address included these words (ref 5, p 27):

> *We have been teaching inappropriate chemistry at the wrong time and in the wrong way. We have been presenting chemistry in a way contrary to what we now know and understand about learning.*

More recently, here is an excerpt from *Reaching Students*,[6] a 2015 publication of the National Research Council. The words are equally strident (ref 6, p xi):

> *More than half of the students who start out in science or engineering switch to other majors or do not finish college at all. Maybe they failed a crucial prerequisite course, or found little to engage their interest in their introductory courses, or failed to see the relevance of what they were being taught.*

How do we find harmony? To answer this question, here is another definition worth our consideration.

Harmony. "A relationship in which various components exist together without destroying one another."[1]

Destroying one another. Really?

Yes, in the sense that general chemistry classes have destroyed the dreams of some of our young people. Ethnographic researchers Elaine Seymour and Nancy Hewitt interviewed students who left science, citing evidence that able and interested students could be retained if greater attention were paid to their poor learning experiences.[7] They point out (ref 7, p 99):

> *[S]tudents caught in [a] downward spiral struggled to reconcile their low grades and feelings of overwhelm with a depleted sense of self-worth or began to recast their career options in light of other talents or interest.*

Destroying one another. Really?

Yes, in the sense that those who left included bright students whose talents are needed by all in the wider society. Recall how Sheila Tobias titled her monograph: *They're Not Dumb, They're Different*.[8] She writes (ref 8, p 18):

> *If the sciences are to attract any new group of students to science, either to meet the projected shortfall or to solve the science illiteracy problem, the effort must begin by getting to know some of "them," and well.*

Getting to know these students includes being struck by the fact that they bring much-needed talents to the chemical sciences.

In our institutions, several different components need to coexist without destroying one another. Which ones? That brings me to the point of this talk: No single factor ensures student success in an undergraduate chemistry course. Rather, it is a blend of several: the faculty, the curriculum, the campus climate, and, of course, the students. When all work together, the resulting four-part harmony is pleasing and orderly. The components co-exist without destroying anyone or anything.

Those speaking in this symposium will describe the ways they have sung a new song and brought harmony to the content and pedagogy of their courses, to their fellow instructors, to the climate of their wider campus, and to their students.

I've already named four of the speakers. Let me introduce you to the others. Rigoberto Humberto, who was the winner of the 2014 ACS National Award for Encouraging Disadvantaged Students in Careers in the Chemical Sciences, and Tehshik Yoon are both tenured chemistry faculty members. Over the years, they have paved a path for success both for their students and with their colleagues. They well recognize how faculty mentoring and campus climate are two critical components of a four-part harmony.

Lawrence Duffy and Linda Nicholas-Figueroa, both of University of Alaska at Fairbanks, have worked shoulder-to-shoulder with Native Alaskan students and their elders. They well recognize how our "disadvantaged" students are simultaneously our mentors and teachers. Together with Matthew Fisher at St. Vincent College, they are part of a 15-year curriculum reform project, Science Education for New Civic Engagements and Responsibilities (SENCER) funded by the National Science Foundation. This project provides a national voice for the needed curricular piece, calling instructors to connect "course topics to issues of critical local, national, and global importance."[9]

To set the stage for their talks and the discussion that will follow it, let me offer one more word for our consideration: disharmony.

Disharmony. "Lack of harmony; something not in accord; a conflict."[10]

For the sake of argument, consider how one might create a great amount of disharmony for a student enrolled in a college general chemistry course. First, mismatch this student with the course in terms of mathematical skills and prior content knowledge. Second, throw in a 20-h-a-week job for the student. Third, encourage instructors to weed out the unworthy and to be "unapologetically competitive, selective and intimidating".[11] Fourth, omit any mention of people—the human element—from the curriculum.[12] Fifth, teach content that is a mile wide and an inch deep, devoid of how chemistry plays a role "for the benefit of Earth and its people".[13] And finally, in the wider campus community, allow a chilly climate on campus to persist year after year after year. Such a climate has been termed "microagressions" against people.[14]

My point in generating a worst-case scenario? If we know how to make things worse for students, perhaps we can reverse our steps and make things better. Much of what produces disharmony is actually under our control.

Disharmony brings me back to the point of this talk: No single factor ensures student success in an undergraduate chemistry course. Rather, our "disadvantaged" students are but one component of a larger educational system. All of the components need to work in harmony, including the campus, the curriculum, the students, and the faculty.

CAMPUS: THE WIDER LIVING–LEARNING ENVIRONMENT MATTERS

Students spend far more time outside our classrooms and labs than in them. And even while in the classroom, they may be communicating with the outside world. The "climate" of their residence halls, campus eateries, libraries, places of worship, student organizations, and recreation spaces all contribute to how welcome, safe, and comfortable a particular student may feel.

The same is true for faculty members, administrators, and student advisors. It is *our campus as well*, and we spend time in many of the same places as do our students. Our responsibilities include making the wider environment welcoming, safe, and comfortable not only for ourselves, but also for our students and colleagues, both current and future.

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CURRICULUM: THE WAY WE TEACH MATTERS

A recent publication of the National Research Council bluntly stated (ref 6, p xi), "A single course with poorly designed instruction or curriculum can stop a student who was considering a science or engineering major in her tracks." The evidence stacks up against science and engineering courses in general (ref 6, p xi):

> *[A] large part of the problem lies in the way these courses are traditionally taught—through lectures and reading assignments, note-taking and memorization, and laboratories with specific instructions and a predetermined result.*

As was the case for the wider campus climate, much of curriculum is under our control. We have the power to establish new traditions for the ways in which our courses are taught.

STUDENTS: WHO OUR STUDENTS ARE MATTERS

Disadvantages or "risk factors" are well-known to all who work closely with chemistry students. These arise for a variety of reasons, including some not directly under the student's control. All risk factors are relative; that is, they depend on how a student stacks up against other students in the course. Risk factors include the following:

- A chilly social climate in the classroom or on campus
- Competing demands on one's time, including needing to work
- Personal or family health issues
- A lack of prior knowledge in chemistry, math, or reading
- A previous poor learning experience in chemistry or math
- Missing study skills or inefficient work habits
- A lack of role models and mentors

Admittedly, *any* student may find himself or herself unexpectedly at risk for dropping or failing a course. The student of most concern in this symposium, however, is the one who walks in the door with several risk factors. Who is at the door to greet these students?

FACULTY: WHO WE ARE MATTERS

We are the ones at the door to greet our students. Or are we? I don't know about you, but on the first day of class I look out on well over a hundred pairs of eyes. They look right back at me; that is, if I can get them to look up from their screens. The ways in which I get to greet my students, interact with them, and perhaps even convince them to spend time learning are now quite different than they were back in the 1970s when we first were trying to teach the world to sing in four-part harmony.

As faculty members, we have changed and surely will continue to do so. But one thing hasn't seemed to change. Each day, when we go about a seemingly endless stream of daily tasks, our heads go down. In front of us we see lectures to write, labs to prep, students to meet, e-mails to answer, and meetings to attend. With our heads down, we may miss the wider system around the student, including parts of our curriculum, parts of our classroom environment, and parts of the wider campus.

If *who we are* is to matter, we need to get our heads up! With our eyes seeing the bigger picture, we can find paths on which we and our students can walk and find harmony.

FINDING THE PATHS TO HARMONY

Three things can help us find these paths. First, we need more ways to describe our students than simply "disadvantaged". Sheila Tobias was the first to point out that our students were not dumb, they were different.[8] In being different, they come to our classrooms with life experiences and expertise. They may be fluent in other languages. First-hand, they may know hunger, injustice, illness, and perhaps even war. Our students are worthy of far more than a single label.

Second, we need to build on the work of those who have acted over the years, bringing harmony to our lives and the lives of our students today. Many have contributed to making our chemistry classes better for our students, including those in our communities, educational researchers, administrators, thought leaders, those in funding agencies, and staff members in professional societies. Some we have met and can thank, including those in the symposium with us today. But others we will never meet but nonetheless can honor by moving their work forward.

Third, as individuals we need to pay it forward. We are the people who make things better for students and teachers in the future. Just as those in the past have helped tune the different voices, we need to create conditions under which we as faculty members, together with our students, our curriculum, and the wider campus environment, can work together in harmony in the semesters to come.

Please allow me to conclude by returning to where we started. Harmony is an orderly or pleasing combination of elements in a whole. There is no single way for a person to join in creating this harmony; rather, the invitation goes out to all to find their voices and to sing their parts.

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Notes

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REFERENCES

(1) The Free Dictionary, entry word "harmony". http://www.thefreedictionary.com/harmony (accessed Aug 2015).

(2) The Hillside Singers, I'd Like To Teach the World To Sing (in Perfect Harmony). Metromedia, 1971. http://en.wikipedia.org/wiki/I%27d_Like_to_Teach_the_World_to_Sing_%28In_Perfect_Harmony%29 (accessed Aug 2015).

(3) Middlecamp, C. H.; Kean, E. Special Programs for Special Students: I. Providing Assistance to Nontraditional Students. *J. Chem. Educ.* **1983**, *60*, 960−961.

DOI: 10.1021/acs.jchemed.5b00383
J. Chem. Educ. XXXX, XXX, XXX−XXX

(4) Kean, E.; Middlecamp, C. H. Special Programs for Special Students: II. Design of Assistance Programs for Nontraditional Students. *J. Chem. Educ.* **1983**, *60*, 1055−1057.
(5) Johnstone, A. H. You Can't Get There from Here. *J. Chem. Educ.* **2010**, *87* (1), 22−29.
(6) Kober, N.; National Research Council *Reaching Students*; National Academies Press: Washington, DC, 2015.
(7) Seymour, E.; Hewitt, N. M. *Talking about Leaving: Why Undergraduates Leave the Sciences*; Westview Press: Boulder, CO, 1997; p 99.
(8) Tobias, S. *They're Not Dumb; They're Different*; Research Corporation: Tucson, AZ, 1990.
(9) Science Education for New Civic Engagements and Responsibilities. http://www.sencer.net/ (accessed Aug 2015).
(10) The Free Dictionary, entry word "disharmony". http://www.thefreedictionary.com/disharmony (accessed Aug 2015).
(11) Malcolm, S. Stemming the Science Shortfall at College. In *They're Not Dumb; They're Different*; Tobias, S., Ed.; Research Corporation: Tucson, AZ, 1990; p 9.
(12) Mahaffy, P. The Human Element: Chemistry Education's Contribution to Our Global Future. In *The Chemical Element*; Garcia-Martinez, J., Serrano-Torregrosa, E., Eds.; Wiley-VCH: Weinheim, Germany, 2011.
(13) American Chemical Society Web page, Mission Statement, http://www.acs.org/content/acs/en/about/aboutacs.html (accessed Aug 2015).
(14) Caplan, P. J.; Ford, J. C. The Voices of Diversity: What Students of Diverse Races/Ethnicities and Both Sexes Tell Us About Their College Experiences and Their Perceptions About Their Institutions' Progress Toward Diversity. *Aporia* **2014**, *6* (4), 30−69. http://www.oa.uottawa.ca/journals/aporia/articles/2014_10/Caplan_Ford.pdf (accessed Aug 2015).

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