NATURAL SCIENCES

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In his overarching paper on the mission of Santa Clara University in a globalizing world, Mark Ravissa reminds us that as a *Catholic Jesuit* University, we must engage in the "pursuit of truth and goodness" in a way that produces leaders of "competence, conscience, and compassion", who are committed to "fashioning a more humane and just world." Studies in the natural sciences will provide many avenues for our students to fashion a better world.

From family to global, scientists must function within many communities. Our challenge as scientists at SCU is to make sure we are connecting sufficiently within and across communities to facilitate the development of students who will be leaders of competence, conscience, and compassion. In this paper, I will propose why better connections are particularly important in the natural sciences and how they might be achieved.

Connecting Disciplines To Each Other

First, we must educate students who are *competent* to function as scientists in the future scientific world. The interplay of diverse disciplines has recently led to important scientific discoveries, which are transforming the landscape of our scientific world. For example, the convergence of recombinant DNA technology, instrumentation, and information technology led to the deciphering of the human genome. According to a recent National Research Council-sponsored report, research in the natural sciences is becoming increasingly interdisciplinary and the connections between all areas of science are rapidly becoming deeper and more extensive. In contrast, undergraduate education in the natural sciences has changed very little during the past few decades[1]. We need to educate our students for a future in which math, physics, chemistry, and biology majors can connect and apply their skills to create an interdisciplinary whole greater than the sum of its parts.

There are several levels at which this can occur, ranging from entire courses of study to single modules within individual courses. An example at one extreme is the integrated first-year science course at the University of British Columbia that melds biology, chemistry, math and physics together, giving students a sense of interconnections at the beginning of their college education[2]. This would obviously require significant commitment from several members of each science department and is probably too ambitious for SCU at this stage. The next level would be the development of interdisciplinary major or minor programs, a good example being our Environmental Studies Institute. I suggest we explore other possibilities. Some that come to mind are programs in biochemistry, nanotechnology, astrobiology, neuroscience, or bioengineering. An interdisciplinary program in biochemistry would require very little additional effort to develop and launch, while interdisciplinary programs in nanotechnology, astrobiology, neuroscience, and bioengineering would reflect current exciting areas in science and would involve more than just two departments. Although interdisciplinary programs represent a more coherent picture of interconnections between disciplines, sometimes individual courses are more appropriate and are certainly easier to develop and implement. These could be full-fledged permanent courses or topical seminars that vary from year to year. As suggested by the BIO 2010 Report, one way to enter the interdisciplinary realm is to develop interdisciplinary modules within existing courses[3]. For example, an organic chemistry course at U.C., Berkeley includes a module explaining how flu virus recognizes the carbohydrates on our cells and how understanding the chemistry of those carbohydrates led to the development of some flu drugs[4]. Many faculty already practice this type of interconnection to some extent, but it could be more widely adopted. Furthermore, most faculty attempt this difficult process on their own; the creation of interdisciplinary modules would be best accomplished by a team of faculty from different disciplines.

While it is clear that our curriculum needs to become more interdisciplinary, it is necessary to point out some caveats regarding the development of interdisciplinary courses. They are difficult and time-consuming to develop, requiring time beyond that required for the development or modification of a single-discipline course. Faculty need to be given time and incentives to tackle these projects. Also of concern is how teaching credit is to be assigned. If the course is team-taught, the interweaving of more than one discipline requires more than the half-time teaching credit that is awarded in these situations. Students also need to receive appropriate credit for taking an interdisciplinary course. If no department will allow a course to count for its major, then who will take the course? A further danger in the development of interdisciplinary courses is the creation of courses for the convenience of the faculty, without consideration of need and interest. For example, just because we *can* develop a particular course or program doesn't mean that we *should* develop it if no students will sign up for it, or if they find that the course or program does not help them achieve their post-graduation goals.

These and other issues must be resolved in order to achieve a curriculum that has a truly interdisciplinary nature. The BIO 2010 Report states that "for interdisciplinary education to become a reality, colleges and universities must provide incentives and help eliminate disincentives to interdepartmental collaborations".5

Connecting To The Public

Scientists are part of a larger community and it is imperative that we communicate effectively with, educate, and understand that community. The societal impact of scientific advances will continue to increase. Decisions regarding the application and ethics of such advances will require an informed public. One way to educate the public is through our *non-science majors*. One or two token science courses are not enough for a future filled with interconnected scientific and technological advances.

We should make science more accessible to our non-majors by providing interdisciplinary stand-alone science minors and seminar courses. Many students have an interest in science, but are not willing or able to commit to the plethora of courses required to achieve a science degree. Yet, many of our students will be future leaders and policy-makers and will need to make important decisions based on their understanding of scientific and technological concepts. We should ask ourselves if we are providing these future leaders with the necessary knowledge and understanding of connections to navigate through the sea of scientific advances in their future. I am not advocating a *requirement* for more science courses for our non-science majors (they have enough required courses already), but rather to give interested non-science majors the opportunity to take science courses that will not only convey the excitement of science, but will also allow students to see the connections between different disciplines, scientific and otherwise.

In their 1999 Report, the members of the Committee on Undergraduate Science Education (CUSE) asked executive and academic officers of postsecondary institutions to provide "incentives for individual faculty and departments in SME&T[science, mathematics, engineering, and technology], the humanities, and the social sciences to work together to develop introductory interdisciplinary courses that are meaningful for *all* students, including both those who are and who are not likely to major in the faculty members' disciplines."[6] While some of our University core science courses for non-science majors are interdisciplinary, the Intro courses for our science majors are typically narrowly-focused on a specific topic within a single scientific discipline. We need to develop more broadly-based courses and programs that better reflect the increasingly interdisciplinary nature of science today.

There are at least two advantages of developing a stand-alone minor. First, science and non-science majors would interact and talk about *science* in a *science* class, something that doesn't typically occur. This would provide a wonderful opportunity for them to *connect* to each other. Second, non-science majors will be able to achieve a deeper level of understanding of a particular science topic than is currently possible for them. One example of a possible stand-alone minor would be astrobiology, which could include courses in biology, chemistry, physics, mathematics, and engineering. The true interdisciplinary nature of astrobiology makes it an ideal framework through which to integrate a wide range of scientific, ethical, and even religious topics in a natural and compelling way. The astrobiology minor and seminar courses would provide opportunities to discuss ethical and societal issues and could easily be designed to satisfy the five criteria for a civic engagement course proposed by Janet Flammang in her paper on "Civic Learning and Educating for Democracy."

Connecting To Future Teachers

Very few of our science majors become high-school science teachers. Liberal arts majors can teach science at the elementary school level, but a strong science background is required to effectively teach high school science. Current state requirements make it very difficult for our science majors to become certified to teach high school science. While we cannot change state requirements, we can strive to make it easier for our students to choose this career path. One approach would be more aggressive and supportive advising of our majors about careers in teaching. We could also explore the possibility of developing, in collaboration with our Department of Education, a 5-yr program for a Master's degree in Science Education. By increasing the number of SCU science student teachers that are trained in the Jesuit tradition, we create a golden opportunity for thousands of high school students to learn science under the guidance of teachers trained to be ethical leaders and citizens.

Connecting To Our Own Discipline.

Finally, the BIO 2010 Report recommends that "project-based laboratories with discovery components replace traditional scripted 'cookbook' laboratories."8 Authentic research experiences for students are very effective in engaging their interest and also will expose them to realistic scientific questions, interdisciplinary aspects, and opportunities to work cooperatively. There are two main approaches to achieving these authentic laboratory experiences. One approach is to facilitate student research on and off-campus. Some departments already do this very effectively by obtaining funding for student research programs and giving credit for off-campus research internships. An indication of strong university support for these authentic research experiences would be to give faculty teaching credit for supervising research students. Most science faculty train and educate these students not just because they help us do our research, but because we believe that this type of teaching is an extension of our roles as teaching scholars. The training and supervision of these students represents a significant commitment of our time and should be recognized. Another approach to give students authentic research experiences is to encourage the development of project-based laboratories, in which the laboratory exercises are focused around a real research project. These project-based labs often require more resources than more traditional labs.

Faculty Scholarship.

In order for faculty to effectively teach their subject and engage in interdisciplinary interactions, they must be deeply steeped in their own discipline. There are also special concerns for those disciplines in which the techniques of research change rapidly, making it more challenging for faculty to stay connected to recent advances in their discipline. Thus, among other things, strong support of faculty scholarship in the natural sciences is manifested by a strong sabbatical policy and consistent and significant support for travel to attend conferences where exchange of ideas can take place.

Connecting Through our Centers of Distinction.

Our Centers of Distinction give us an ideal way to facilitate connections. The Center for Science, Technology, and Society is by its nature interdisciplinary. It has successfully integrated various aspects of information technology, business, law, and sociology. This center is also acting as a focal point to integrate the natural sciences with other areas, such as globalization. Further integration of the natural sciences into this program would enhance its efforts. For example, the effects of biotechnology on society would be a good source of interdisciplinary topics. In addition, the Bannan Center for Jesuit Education would be an ideal focal point for interdisciplinary discussions on science and religion. Finally, as our science majors embark upon careers in the sciences and our non-science majors are faced with ethical issues arising from science and technology, both groups of students will need to take with them the ability (and inclination) to understand, reflect upon, debate, analyze, and act upon the ethical challenges they will face. Although one "ethics" course is required of all SCU graduates, Paul Fitzgerald in his paper on "Ethics and Justice" challenges us to further expose students to "rigorous, applied ethics courses that examine truly ambiguous and vexingly difficult situations". In addition to these explicit ethics courses, he also asks us to "weave this search for truth, mercy and courage throughout the social fabric of the university". The study (and practice) of the natural sciences affords many opportunities to raise ethical questions and thread them into our curriculum. Many science courses already do this to some extent. We should continue to encourage this and strive to add even more of these threads to our tapestry of science. The Markkula Center for Applied Ethics is already very effectively integrating the natural sciences with ethics and social justice into our curriculum. The center has created new programs and courses, in addition to helping faculty bring ethics into existing natural sciences courses. We should continue to support and encourage these efforts.

Conclusion.

The four characteristics of a Catholic, Jesuit education delineated in Mark Ravizza's paper on mission resonate strongly with education in the natural sciences. As medical doctors, research scientists, conservation biologists, dentists, production chemists, bio-engineers, science teachers, etc., many of our science graduates will eventually be in positions to alleviate human suffering, protect the environment, and improve the quality of life. This directly applies to the first two characteristics in Ravizza's paper, "the glory of God and the common good" and "in solidarity with those most in need". The third feature of the Jesuit tradition is described in Paul Crowley's paper on "Theology and Culture" as "a keen sense of the transcendent in everyday life". Ravizza interprets this to mean that "in our pursuit of truth, we cannot ignore or dismiss difficult issues of meaning and transcendence" and that SCU must be a place that "actively encourages academic inquiry to grapple with ultimate questions of values, morals, and religious significance." The natural sciences are rich with such questions, and we need to foster an environment that encourages our students to thoughtfully explore them. According to Ravizza, however, these explorations will require acceptance of the fourth characteristic of a Jesuit education, "embracing a creative tension". As part of their Catholic Jesuit education, our science and non-science students should learn that competing goals need not paralyze them, that they can have the courage to wrestle with ethical issues in science and technology, and that they have developed the skills to do so intelligently.

Reflectors

Bob Bekes, Jim Grainger, Phil Kesten, Dave Tauck, Amy Shachter, Atom Yee

References

[1]BIO 2010: Transforming Undergraduate Education for Future Research Biologists. (Committee on Undergraduate Biology Education to Prepare Research Scientists for the 21st Century) (The National Academy Press, Washington, D.C., 2003) p. 1.

[2]ibid. p. 95.

[3]ibid. pp 61-66.

[4]http://mc2.cchem.berkeley.edu/modules/flu/

[5]BIO 2010: Transforming Undergraduate Education for Future Research Biologists. (Committee on Undergraduate Biology Education to Prepare Research Scientists for the 21st Century) (The National Academy Press, Washington, D.C., 2003) p. 104.

[6]Transforming Undergraduate Education in Science, Mathematics, Engineering and Technology (National Research Council, 1999) p. 5.

[7]BIO 2010: Transforming Undergraduate Education for Future Research Biologists. (Committee on Undergraduate Biology Education to Prepare Research Scientists for the 21st Century) (The National Academy Press, Washington, D.C., 2003) p. 96.

[8]ibid. p. 75.