
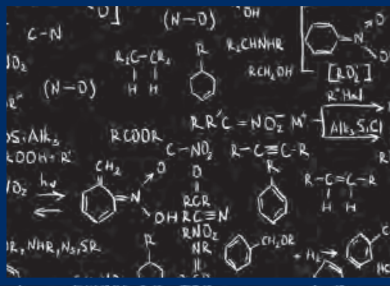
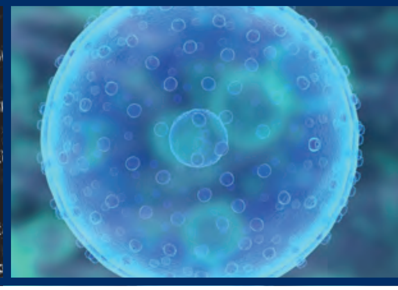


# SCIENCE EDUCATION & CIVIC ENGAGEMENT

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# Contents

# From the Editors

We are pleased to announce the Winter 2013 issue of *Science Education and Civic Engagement: An International Journal*. This issue continues our mission of publishing articles that share innovations, insights, and assessment results with an international community of educators.

In the *Research Article* section, a group of colleagues from Brigham Young University—**Jessica Rosenvall Howell, Michelle Frandsen McDonald, Pat Esplin, G. Bruce Schaalje, and Gary M. Booth**—describe a survey of faculty members, biology majors, and undergraduate non-majors., where each group was asked to rank what biology concepts they considered most important. There were significant differences among the groups' rankings; for example, one of the greatest disparities was observed for the concept of "evolution." This study reveals t how faculty members and students have different viewpoints about the same the same course material, and the authors provide suggestions for how this mismatch can be addressed.

This journal issue contains four contributions to the *Project Reports* section. A team from the United States Military Academy at West Point provides an initial report about "Putting the Backbone into Interdisciplinary Learning." These authors (**Charles Elliot, Gerald Kobylski, LTC Peter Molin, Craig D. Morrow, COL Diane M. Ryan, Susan K. Schwartz, Joseph C. Shannon,** and **Christopher Weld**) describe an interdisciplinary learning initiative organized around the concept of "energy." In another report, **G. González-Arévalo** and **M. Pivarski** from Roosevelt University explain how they integrated real-world projects into a calculus II course with the goal of increasing student interest and engagement—examples include the Deepwater Horizon oil spill and the spread of HIV/AIDS. **Devin Iimoto** (Whitter College) provides an account of integrating service-learning in a course on the biology and cultural context of AIDS. Finally, **Kevin E. Finn** and **Kyle McInnis** from Merrimack College describe the development of an "Active Science" curriculum in which physical activities are incorporated into science classes and after-school programs for middle-school children.

We want to thank all the contributors to this issue for writing and sharing these articles.

— *Trace Jordan and Eliza Reilly*
Co-editors in chief

PUBLISHER'S NOTE

# Some Thoughts on the Benefits of Long-term NSF Support:

## What I Would Have Said if I Had Time to Say it

**Wm. David Burns**

*Publisher, Science Education & Civic Engagement—An International Journal*

Transforming Undergraduate Education in STEM: Building a Community to Transform Undergraduate STEM Education *was the title of the 2013 TUES Principal Investigators Conference, organized by the National Science Foundation and the American Association for the Advancement of Science and held from January 23-25 in Washington, DC. About 550 PIs attended.*

*The opening plenary session was a panel moderated by Bruce Alberts, editor-in-chief,* Science, *professor of Biochemistry and Biophysics, University Of California, San Francisco (UCSF), and president emeritus, U.S. National Academy of Sciences. According to the organizers, the panel "included six presenters from different scientific disciplines who had funding from TUES/CCLI for 10 years or more."[1] I was honored to be among them. Panelists were requested to "discuss 'synergies' and research sustainability that long term funding has made possible (understanding that the funding is segmented into a series of grants), including having good evidence that your project improved undergraduate STEM education." Panelists were also asked to discuss "lessons learned, including:*

- *Challenges and how you overcame those challenges;*
- *Unanticipated outcomes;*
- *What internal and external resources and support you needed to build and sustain a long-term program, other than more grant funds; and*
- *What keeps you going."?[2]*

*Each panelist was allocated five to seven minutes to make a presentation. Those who know me most likely would believe that it is more likely that that famed Biblical camel will pass through the eye of the needle before I could speak for just five minutes, or even seven, on one question, let alone a half dozen. But you would be wrong. As it turns out, I was the only speaker who stayed under the time limit (a fact noted and remarked upon by those who knew me who were in attendance).*

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1 The other panelists were: Nathan Klingbeil, Senior Associate Dean and Professor Mechanical & Materials Engineering, Wright State University; Cathy Manduca, Director Science Education Resource Center - Carleton College; Pratibha Varma Nelson, Professor of Chemistry and Executive Director, Center for Teaching and Learning, Indiana University Purdue University Indianapolis; William Oakes, Associate Professor, School of Engineering Education and Director, Engineering Projects in Community Service (EPICS), Purdue University; and, Katherine Perkins, Associate Professor of Physics, Director of PhET Interactive Simulations Project and Science Education Initiative, University of Colorado Boulder.

2 These goals are taken from a January 9, 2013 e-mail from Yolanda George of AAAS.

*I had been intrigued by the questions, however, and though I knew that I could not even begin to answer them in the allotted time, I prepared some notes and remarks. As many of the questions were of the same general character as those I posed to myself and answered in the two-part series,* "But You Needed Me-Reflections on the Premises, Purposes, Lessons Learned, and Ethos of SENCER,"[3] *readers who know those pieces will find some of this to be familiar. I offer what follows as a version of what I would have said had time and circumstances permitted me to do so.*

*I thank Myles Boylan and Don Millard of the NSF for inviting me to participate. My prepared remarks follow.*

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First, congratulations to all of you who are here.

I wish you great success with your work. I invite you to use the resources of our National Center and SENCER in any way that would help you achieve your goals.

Given how tough it is these days to earn the opportunity to be in this room, my congratulations are heartfelt.

In thinking about my own situation, I have recalled the consolation I once offered a terrific student who had been rejected by Harvard's Kennedy School.

"Admission," I told him, "was an accident on the road to rejection."

Much as I think SENCER's work is praiseworthy, I remind myself that we exist because we too are an accident on the road to rejection, so to speak.

Thus, I expect I represent you as well when I say I am truly grateful to the US Congress, to the President, to the NSF—and especially to all who pay taxes that make the NSF's work possible—for the chance to do what we do.

Long-term NSF commitment to a mission that embraces advances in scientific knowledge as well as advances in the public's knowledge of science provides the framing context for the work we have to do for our nation. (We owe a debt of gratitude to Bruce Alberts for championing not just science education but this latter goal as well, a goal that goes far beyond the replication of a scientific research elite.)

NSF's support, guidance, and funding for SENCER have enabled us to labor in support of that mission. This support has also made it possible for us to meet that most basic ontological challenge: **existence,** something my mother would have described as "a mere detail"!

I won't say it is the difference between "being" and "nothingness", but it sure comes close!

If I had to sum this up in one statement, it would be this: long-term NSF support is what has empowered a sustained, extensible, and growing **movement** for STEM education reform.

So what does SENCER do? I have made a handout available, but, in brief, in connecting STEM "learning and doing" with some of the most "complex, capacious, contested civic challenges of our time," we deliberately

- try to **do more than one thing at once**: specifically we work to improve STEM education and stimulate civic engagement, [4]
- **focus on the "science for all" challenge** (an opportunity made possible, as I said, in part thanks to the leadership and legacy of Bruce Alberts),
- empower faculty and students to **make STEM learning real, relevant, responsible and rigorous** (while fighting against the impulse to confuse rigor with failure),
- **bring the science of learning to the learning of science**,[5]
- **explore connections between scientific practice and democratic practice,**
- **build an extensible and growing national "movement,"**
- **support that movement with resources, assessment tools, rewards and connections,**
- **contribute to the STEM education knowledge base,**[6] and
- **serve the public good.**

3 http://seceij.net/seceij/summer11/burns_part_1_yo.html

4 This embraces the ecological and economic notion that "you can never really do only one thing."

5 This is a central SENCER tenet: actively aligning our work with what is know about "How People Learn" (cf, Bransford, Duschl, and others) at least at the level of organizing "theory" and increasingly, with oru rubric and other devices at the level of implementation.

6 See www.sencer.net for resources (models, backgrounders, assessment tools, etc) and www.seceij.net for our on-line, peer-reviewed publication.

### *Synergies Made Possible By Long-Term Support*

Synergy is a good organizing notion for mapping one region of this broad territory. Long-term, continuous (though sometimes tenuous) support has enabled us to develop and sustain what I believe are the key drivers of change:

- Having a **good idea,**
- Organizing and supporting a **community of practice** dedicated to bringing the idea to life,
- Supporting that community and **strengthening relationships over time,**
- **Welcoming newcomers** not just to join but also to shape our efforts,
- **Encouraging "alumni"** to push the envelope and influence our agenda,
- **Achieving "noticeable" scale** (some 10% of US institution of higher education, so far),
- **Being strategically opportunistic,** taking advantage of new collaborative opportunities,
- Listening actively (engaging in ongoing formative assessment),
- Refreshing our approach in light of what we learn,
- Inviting participants to become new leaders,
- **Distributing leadership opportunities and responsibilities,**
- **Rewarding achievement**, and
- **Collaborating with others** who are similarly engaged.

New synergies have enabled new engagements, you could say, and added new responsibilities, as well. I will mention just a few specifically:

- **We've given broader distribution to work already supported by NSF**: Barbara Tewskbury's Geology and Africa course is a good example. Originally created with NSF support before there was a SENCER, Barb graciously allowed us to use the course as "a SENCER model." That use resulted in a broader impact for that NSF investment than had been envisioned or promised by Barb in her original application for NSF funds.
- **We've provided "alpha testing" for a series of projects that have been developed more fully and disseminated with subsequent CCLI/TUES support:** We have made more than 300 "NSF-supported sub-awards" to support innovation, faculty development, and alpha testing of new ideas. Several of these have become the basis for successful new TUES I applications to NSF and other extramural support.
- **We've learned from the advanced thinking of others:** We have been inspired, for example, by EPICS, because engineering the way EPICS supports it is very "SENCER-y" in that it is the perfect model of a discipline that negotiates the complex intersections of human desire and the "laws" of science.
- **We've developing and shared a Digital Library Collection of our resources:** With the help of Kathy Manduca and Sean Fox of Science Education Resource Center (SERC) at Carleton and with Claire McInerney and the colleagues at the Rutgers School of Communication and Information, this asset has been developed, is added to regularly, and is now freely available to all.
- **We've launched a new SENCER-ISE II project:** Growing out of an observation that the SENCE approach applied the principles of informal science education (ISE) to formal learning, this new NSF-supported project will forge collaborations between higher education and ISEs on matters of civic consequence. This is a project that, in a small way, is designed to deal with another issue Bruce Alberts (and Jay Labov) identified when they said that, for most college's students, the introductory course in STEM is sadly also the terminal course.
- **We've organized and supported new regionalization initiatives:** Our nine regional SENCER Centers for Innovation (SCI) are directly supported with NSF funds. Their success inspired us to request and receive support from the W.M. Keck Foundation for the development for seven nodal partnerships across the West. The GLISTEN project (focused on the Great Lakes) was a direct outgrowth or regional work undertaken by our Chicago-based SCI. A new grant from the EPA will enable continuity and growth in science education, student-led research and service learning in the Great Lakes region.
- **We're cultivating ongoing collaborations with organizations with interests in common:** New

collaborations include those with the Council of Colleges of Arts and Science (CCAS), Hispanic Association of Colleges and Universities (HACU) and the White House Office on Historically Black Colleges and Universities.

As I noted, all of these collaborations and new initiatives share a basic ontological requirement: that there be a "we" that "they" or you can collaborate with! This is a matter absolutely essential I think when we consider the scale and scope of the STEM education reform challenge we face.

## *Research Made Possible by Long-term Sustained Support*

Scale, scope and, especially duration (longitude) have enabled our partners and ourselves to:

- **develop, test and refine a national assessment resource, the SALG and SENCER-SALG.** Elaine Seymour, our original evaluator of SENCER saw in SENCER the opportunity to further develop, test and validate the SALG[7] , an instrument she had initially created in connection with an NSF-supported project in chemistry education. Now the SALG, with additional support from the NSF, has been enhanced and is being employed by a growing community of users to encourage students to reflect on their own learning and help professors improve their instructional strategies. Steve Carroll, the SALG PI, is attending this meeting and has a poster on the project,
- **engage in and produce "scholarship of teaching and learning" (SoTL).** Members of the SENCER community have been engaged in envisioning, designing, conducting and publishing research on the effectiveness of their STEM education reform interventions, though workshop training in the SoTL at Summer Institutes and regional meetings,
- **launch a peer-reviewed on-line journal to provide broader impacts for SENCER-initiated and other related work.** *Science Education and Civic Engagement—An International Journal* was originally conceptualized by SENCER co-funder, Karen Oates, as a vehicle supporting the community of practice and specifically as a strategy to strengthen global partnerships, such as those she had established with the newly independent states of Georgia, Armenia and Azerbaijan and those begun with our AAAS-partnerships in Africa. The journal, in its sixth year, is now "published" twice annually,
- **organize our own formative assessment/research program.** Learning as we go and going on as long as we have has enable us to acquire a library of assessment and evaluation materials on each of our institutes and other national programs, to conduct periodic focus groups and survey research initiatives. The most recent of the latter was a survey of past participants in our formal education programs that yielded significant findings about the extent to which participation in SENCER had, for example, over time, resulted in respondents achieving promotion and tenure or promotion after tenure [n=~200]. These and other findings are reported in the new American Chemical Society/Oxford University Press book, <u>Science Education and Civic Engagement: The Next Level</u> (2012, hardcover: 2013),
- **disseminate and support important emerging national STEM education reform initiatives:** Because we have a large national community of participants (~2,500) who receive our bi-weekly e-newsletter, we have been well-positioned to assist in getting the word our on the new science standards, for example, or to encourage our community to read Rick Duschl et al's <u>Taking Science to School,</u> to apply his Evidence/Explanation continuum (along with our Rubric 2.0) to their work, to participate in the Vision and Change initiative and support the nomination of PULSE scholars, and to promote the goals of the NRC's *Thinking Evolutionarily* project, to name just a few, and
- **envision and enact an emerging partnership with College Board** related to the revisions in the AP program that will help assess the "enduring understandings" achieved by students in the SENCER STEM courses.

7 SALG stands for "student assessment of their learning gains" (see: www.salgsite.org for more details)

### *Challenges Faced and "Overcome"*

Our work has not been without many challenges. I will mention a few and touch on strategies that seem to be helping us overcome them:

**Proportionality:** We are blessed with substantial resources (a new TUES III award, for example) from NSF, but the scale of needed reform is enormous. For example, our TUES III award for the next four years is about 1/10 of the annual budget for life sciences of just one member institution in the AAU with which I have some passing acquaintance. The overall TUES budget may be substantial, but it is tiny in comparison with the scale and "wealth" (not to mention the mass and "inertia" of the enterprise that is the target for "transformation"). So, like NSF, we have to use leverage in a currency that is understood on campus (small, targeted sub-awards, for example, >300 so far) and we cultivate volunteer leadership and labor.

**Academic Accountancy:** Integrative, collaborative, cross-disciplinary work is underdeveloped territory, especially at the level of administration. Everybody is for "interdisciplinarity," but few have figured out how to organize, staff and pay for it. So we pay close attention to faculty members who have evolved and figured out strategies that work, such as course intersections (like the Vassar model on our website), cross-teaching (scheduling linked courses at the same time, but switching teachers back and forth), learning communities, organizing a narrative spine (as at West Point in the energy program) and other novel, clever and sometimes subversive acts. We provide connections and consultation to academic leaders who want to change these conditions.

**Rewards:** As some of you no doubt know first hand, adopting progressive pedagogies can be harmful to your careers. So we work to provide recognition and rewards that have CV value to our collaborators/partners (as noted, >200 have reported gaining tenure/promotion due, in part, to their association with our work). The NSF "imprimatur" is critical to making this work on campus.

**Marketing:** We spend so little time, money and energy on marketing (in part because we don't have a surfeit of any of these commodities). This limits our reach. So we rely on other networks and "mobility" to help spread the word. Our "alumni" move to new institutions and work to bring the program there. We've found this "word-of-mouth" endorsement to be the most effective marketing strategy, though it suffers from a degree of randomness and unpredictability.

**Continuity:** Our alumni come and go and we have limited capacity to stay in touch, to follow up years afterwards. We're still working on this, but we hope our program of Leadership Fellows and the reinstated sub-award program with a cadre of mentors will enable us to maintain connections and promote continuity.

**Access:** There's no question that the conditions on campus (workload, growth in contingent faculty ranks, budget cuts, travel restrictions, etc) and our new "business plan" (i.e., passing costs on to users) necessitated by changes in funding availability have affected access to our resources. So we have encouraged robust regional networking (and increased social networking, too, though hardly overdeveloped at this point), and we are creating, with NSF's support, a modest program to assist folks who would otherwise be unable to afford to participate in our Summer Institutes, for example.

**Uncertainty:** While we all live with it and some of us celebrate it when we are speaking in the abstract, it has been difficult to plan long-term interventions and programs in the absence of a long-term funding platform. So we will be doing some serious planning (and so equally serious hoping and helping, if asked, in respect to the development of new mechanisms—funding programs—that will increase access to proven programs, while assuring the expansion of opportunities for newcomers and new ideas and a fresh approach to assuring accountability).

### *Unanticipated Outcomes Experienced*

Have we had unanticipated outcomes? Have we! In some ways, most of the really interesting things that have happened were never really envisioned by my founding partner, Karen Oates, and me, when we first pitched the SENCER idea to Myles Boylan at NSF. I will mention only five:

1. **We have helped teachers change their teaching practices, not just their courses.** We thought we would be helping faculty change courses and we did. In the process, however, faculty members have changed their ideas about teaching all students. This is a much larger and more enduring outcome than we anticipated, though one that was anticipated in a way by one of the reviewers of our initial proposal (you may be in the room: thank you).
2. **Students don't initially like change any more than faculty members do.** Many students, including especially students who have succeeded in the old pedagogies, are initially resistant to new pedagogies because these practices expose them, just as they do new teachers, to risks. So we have to work to overcome this—and one way is to focus on being transparent about learning goals.[8]
3. **Engaging community colleges is essential but it is tough.** Given the crushing faculty workloads, and the pressure on community colleges (and lots of other colleges, as well) for uniformity or at least making courses totally fungible, this has been difficult. We have had success and indeed have course models that were developed at community colleges. However, where we advocate hand-crafted courses that strengthen faculty authority and engage with real student interests or local and community-based civic problems, the trend seems to be in the direction of transferring the "factory model." This is lamentable, to say the least, and it remains to be seem whether the MOOC movement will enable "flipped classrooms" that will make way for SENCER innovations, or if they will represent a cyber-enabled hegemony that no textbook author has ever dreamed of!
4. **Things have been accomplished that we never imagined even in our dreams.** To end this list on a less bleak note, we have been amazed by the local, regional and even global reach that time, talent, and imagination have engendered, from students changing campus energy use practices, affecting local health regulations, enacting regional conservation practices, all the way to forming a high school for girls in Kenya. It has been a wonderful to behold what has occurred.

### *What internal/external resources have we used to build our program?*

NSF support was itself a key motivator and influential driver of our success. The NSF "imprimatur" is a critical catalyst for change and widely respected invitation to be engaged. That "validation" (and our ability to deliver on the promises we made to NSAF in the course of our applications for support) has helped us develop new internal and external recourses. Chief among these, I would say, is the "intellectual capital" contributed by our members, the matching and in-kind financial support for our subgrantees institutions, the generosity of our volunteers, the energy of our campus student leaders, the wisdom of our collaborators from National Research Council and many other places, the legitimacy the members of our advisory board have conveyed upon our work, and the critical support from other sources, like The W.M. Keck Foundation, the Noyce Foundation, the Corporation for National and Community Service, the EPA, and anonymous donors.

### *What keeps us going?*

This is a great question. You probably already know some of the answers. Here's my short list:

**Eros**—We reconnect folks with the original objects of their desire. It is that idea of love that seems to describe and explain the loyalty and devotion of the community and of the members of the community and their work with students.

**Success**—The results are pleasing to participants (and to us) even though the work is hard. A commitment to student success seems to create conditions that

8 See my article, "With Friends Like These" at http://serendip.brynmawr.edu/sci_cult/scienceis/burns.html

lead to that success.[9] When you identify your success as a teacher with the accomplishments of your students, it changes the moral conditions of the classroom, itself.

**Colleagues—**There is no doubt that what has fueled and nourished our desire to continue with the SENCER project and to do the work and undergo the stress that accompanies depending on raising funds and support for the continuity of the work is a sense of obligation to those who have undertaken this work with us.

**Flexibility and Partnership—**We have been blessed with a program officer at NSF who has encouraged us to act like natural scientists and allow reality to shape our planning. I used to joke that Myles Boylan was my "probation officer" and, of course, there is a grain of truth in that remark. He is a part parole officer, surely, who keeps us to our word, but he never holds us to do something we now have reason to think will not work. Our community regards him as a wise counselor and partner in our endeavors.

**Taking a Long-Term View—**Gertrude Stein wrote that "before the flowers of friendship ended, friendship ended." That's true of a lot of grant-funded projects. The commitment goes even before the money gets spent. We have never conceived of our project as having a beginning, middle and end. Though this stance has given us a curriculum in the art of living with uncertainty, it has also enabled us to conceive of SENCER as an extensible and dynamic project—indeed, at the risk of repeating this hubris: a movement—that is responding to a critical need.

**A Commitment to Strengthening Our Democracy—**We look beyond helping to create so-called "well rounded" students, or preparing graduates for jobs and careers, as reason and motivators for study in STEM to a larger challenge: we simply will not achieve the promise of a democracy without a citizenry that possesses the intellectual skills that come from excellent instruction and engagement in the STEM disciplines and exercises their right to access the benefits that come from science and scientific research.

WD Burns
*January 23, 2013 (revised and expanded, January 26, 2013)*

## About the Author

*Wm. David Burns* is the founder and principal investigator of SENCER, the NSF-supported national dissemination project. He is also executive director of the National Center for Science and Civic Engagement and professor of general studies at the Harrisburg University of Science and Technology. Prior to establishing the National Center, he served as senior policy director for the Association of American Colleges & Universities (AACU). During his nine years with AACU, he established the CDC-sponsored Program for Health and Higher Education and created the Sumner Symposia dedicated to exploring the power that students have to improve the health of colleges and communities. David is the principal author and editor of *Learning for Our Common Health* and, among other publications, the article, "Knowledge to Make Our Democracy."

9 Not all teachers agree with this, of course; consider an alternative:

The macroeconomics professor who helped shape Paul Ryan is a voluble, passionate supply-sider and self-described "hard-core libertarian" named William R. Hart, known as Rich. Listening to him, you can imagine that you are hearing what Paul Ryan would say if he were not inhibited by the demands of electoral politics. Hart is the opposite of politic — to the point of regularly, publicly denouncing Miami University for what he regards as declining academic rigor and coddling of students, all in the university's pursuit of "money, money, money." Hart is not a coddler. He proudly reports that of the 112 students who took his latest Principles of Macroeconomics exam, 56 failed and 27 got D's.

See: http://www.nytimes.com/2012/11/05/opinion/keller-the-republican-id.html?pagewanted=all&_r=0

PROJECT REPORT

# Integrating Movement and Science to Promote Physical Activity and Academic Performance in Middle School Children


**Kevin E. Finn**
*Merrimack College*

**Kyle J. McInnis**
*Merrimack College*



## Abstract

### *Background:*

Recommendations from leading U.S. health agencies concerned with reducing childhood obesity call for increased physical activity during school and afterschool environments.

### *Methods:*

We developed the Active Science curriculum, which is a variety of activity-based lessons (e.g., nature hike, dance class, walk at local park, treadmill at local YMCA) and incorporated them into traditional science classes and after school programs for middle school children in a low-income, ethnically diverse community. Following the activity experiments, students and teachers uploaded data from devices to an interactive website that provided inquiry-based exploratory learning of science content. Results: Physical activity results showed that the activity portion of the program were consistent with national recommendations for accumulating physical activity. Significant increases in science inquiry test scores from pre- to post were observed.

### *Conclusions:*

The findings from this study suggest incorporating movement into traditional science curriculum helps to promote physical activity and academic performance in underprivileged middle school-age students


## Introduction

Children throughout the US and globally are facing an unprecedented epidemic of obesity. As childhood obesity rates have been rising over the past thirty years, two significant changes have been occurring in American culture. Children's unhealthy eating habits have increased, and the amount of time they spend in physical activity has decreased. Individuals, on average, consume about 200 more calories per day than they did thirty years ago (USDA, 2012). In addition, more American families consume more fast food and sugary beverages and eat out more often than they have in the past (Farooqi and O'Rahilly, 2008). And finally, children are less physically active (White House Task Force on Childhood Obesity, 2010). All of these factors have contributed to the childhood obesity epidemic.

Lack of physical activity is a problem seen both at home and in schools. A substantial challenge facing schools and afterschool educational programs is to develop practical strategies to effectively increase physical activity within the time constraints of their existing curricula. For schools, lack of adequate funding, failing test scores, discipline issues, student/teacher ratio, and reduction or elimination of athletic and/or recreational programs are commonly identified as challenges to the creation of healthy learning environments (Belansky et al., 2009). Even community-based youth centers and school-age childcare settings are often characterized as places where kids are not sufficiently active (CDC, 2007). Thus, innovative approaches during school and out-of-school time that support wellness standards for physical activity are urgently needed.

Multiple strategies for addressing the problem have emerged at various levels of intervention, and in May 2010, the White House Task Force on Childhood Obesity (2010) created a report to the President that sought to develop a set of strategic recommendations. These recommendations endorsed the incorporation of movement and activity into diverse school and afterschool curricular activities, thus offering physical activity as part of academic lessons on subjects such as science, math, and the language arts. The literature suggests that physical activity may impact academic performance through cognitive, emotional, and physiological aspects of learning (Sibley and Etnier, 2003). While such recommendations hold promise for addressing youth obesity, there is a continued need for practical resources that help schools and youth-serving community organizations to implement these strategies (Stewart et al., 2004).

In response to the need for innovative strategies, the researchers developed the Active Science curriculum, which tested innovative approaches that introduce physical activity into traditional school and afterschool childcare programs. This program is intended to leverage kids' interest and engagement in technology to enhance physical activity and promote science inquiry skills. This approach follows national recommendations on Active Education that incorporates activity into the academic learning experience (Active Living Research, 2009). The purpose of this paper is to summarize the Active Science project and present the results from the school-based Active Science intervention.

## Methods

### *Active Science Approach*

At Merrimack College, we have gathered an existing foundation of research that demonstrates that the integration of movement with learning helps to promote physical activity and supports academic performance in school-age children (Finn et al., 2011). Our work is based upon a growing body of research focused on the close connection between physical activity and academic performance among children. In particular, our Active Science research initiative demonstrated that incorporating movement into science lessons helps to promote both physical activity and academic performance in underprivileged middle school-age children (Finn et al., 2011; Finn and McInnis, 2010). Two studies have been performed using the Active Science approach, one in a classroom environment and the other in an afterschool setting. The design and methodology used in the two settings were similar, but only the data from the classroom-based project will be presented in this paper.

### *Science Education and Civic Engagement*

The Active Science initiative has been a research project targeting the improvements in physical activity levels and science academic achievement in middle-school-aged children in a low-income community. With the Active Science program, the researchers are trying to address two significant societal issues facing many children in the United States: childhood obesity and poor science academic performance. In addition, undergraduate students in the Health Sciences Department at Merrimack College have participated as research assistants in all phases of the project. They have been instrumental in the data collection, analysis, and presentation of the findings and have assisted the researchers in taking on this major societal issue of childhood obesity. The Health

Sciences Department has made civic engagement and social responsibility the cornerstone of our program, uniting all facets of a major educational experience that is meaningful and relevant for our students. Our goal is to produce graduates who are professionally competent, who are aware of the complex public issues in health and human performance, and who will continue to seek out opportunities to serve their community. The undergraduate students have been able to experience cutting-edge community-based research while helping to address the major societal issue of childhood obesity.

## Procedures

The Active Science curriculum was an integration of exercise activities and science lessons to promote classroom-based physical activity within a school's existing science curriculum. Active Science was developed utilizing seven lessons of exercise activities and seven lessons of science content. The ideas for the lessons were adapted from frameworks of the existing Science of Energy Balance and We Can! curricula developed by the National Institutes of Health (NIH) and National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK). The lessons introduced concepts of healthy lifestyles through regular physical activity and nutrition, while simultaneously teaching important scientific principles. Collaborating with the science teachers ensured that each lesson supported the particular learning objectives and goals of the school. The Active Science lessons reinforced topics included as part of national and state science standards such as structure and function in living systems, personal health, nutrition, and scientific investigation.

Students and teachers accessed each of the lesson plans and schedule of activities by logging onto an interactive website created by experts in instructional media and web design. The website was used to provide students with an introduction to each weekly topic, describe the goals of each unit, give clear instructions, provide a system for entering activity data, track student and class progress, provide an interactive class forum for discussions, and describe tasks or homework assignments. Moreover, the website was designed to provide the teacher with a convenient mechanism for organizing and delivering each lesson plan in a time-efficient manner.

## Participants

A convenience sample of four science classes was selected at a tuition-free, independent middle school in Massachusetts during the spring of 2010 and 2011. Class enrollment included Hispanic female students with ninety-one percent of the student body qualifying for free/reduced lunch. The four science classes were taught by three teachers and were comprised of fifth- and sixth-grade students (n=47). The school and classes were selected based on teacher and administrator willingness to participate in data collection.

## Instruments

During each lesson, students experienced hands-on data collection by wearing computerized exercise monitoring devices, heart rate monitors, and pedometers, which captured a variety of physical activity data. The pedometer measured distance, estimated calories, and step count data. The heart rate monitor assessed estimated calories, average heart rate, maximum heart rate, and time spent above, below, or within a prescribed target heart rate range. The Polar E40 heart rate monitor and Digiwalker SW-701 pedometer were utilized for physical activity data collection.

To assess science academic gains, the students were given a science pre-test at the start of the curriculum and a post-test at the end of the unit. The researchers and science teachers created the science inquiry skills and content knowledge test which focused on the science content of the Active Science curriculum (scientific method, data interpretation, nutrition, fitness). The purpose of this test was to determine whether students had learned the science inquiry skills and content knowledge at the completion of the curriculum. The science test was distributed by the classroom teacher and was graded by the researcher. The results of the test were anonymous and did not affect the students' overall academic grade in science class.

## Results

### *Science Learning and Physical Activity*

As a powerful example of our evidence, data from our studies showed children's mean heart rates (146 +/- 9 bpm), maximal heart rates (196 +/- 10.6 bpm), steps (3050 +/- 402.7), calories (99 +/- 8.4kcal), and distance traveled (1.1 +/- 0.2 miles) per lesson, while performing the Active Science curricular activities met national recommendations for youth physical activity. Significant improvements in performance on science content and skills tests were observed (43.9% to 66.3%; $p<0.001$) from pre- to post-curriculum, while qualitative and quantitative data supported program enjoyment and engagement.

## Discussion

The Active Science curriculum was developed to provide a framework for integrating physical activity into academic class time. Results from this study reveal that students participating in the Active Science curriculum were able to achieve physical activity levels that were equivalent to or above the adolescent physical activity recommendations from national health organizations such as the Centers for Disease Control, National Association for Sport and Physical Activity, and the US Department of Health and Human Services. Our comparison of the Active Science curriculum and the traditional (baseline) science lessons revealed that the students in the Active Science classrooms accumulated increased amounts of physical activity during the lessons that were statistically significant. These findings indicate that the implementation of the Active Science curriculum not only successfully increased students' physical activity levels during academic classroom time, which was a primary objective for the curriculum, but also that it helped students to reach or almost reach daily recommended amounts of physical activity. This is a very important finding, because this school is located in a severely deprived and under-resourced urban community in Massachusetts, where 47% of children and adolescents are overweight or obese (the highest level in the State); 70% of residents are Latino, and 86% of families live below the poverty level (Massachusetts Department of Public Health, 2010).

Data revealed statistically significant increases in science inquiry skills and content knowledge test scores from pre- to post-test in all four sections of science classes. Differences in performance on the science inquiry skills and content tests were observed with a 22.4% increase (43.9% to 66.3%; $p<0.001$) from pre- to post-test. Many schools have significantly downsized physical activity programs due to budgetary constraints and increasing pressure to improve standardized test scores. Proponents of school-based physical activity programs have argued that physical activity improves academic performance and that regular exercise improves students' concentration and cognitive functioning (Castelli et al., 2007). The Active Science data support these findings by suggesting that including physical activity as a part of academic lessons can facilitate student learning and that the inclusion of physical activity by no means adversely impacts academic performance in classes. This classroom-based physical activity approach is one way to get students physically active while still promoting learning in the classroom. The positive results from this study examining the Active Science curriculum, which is an example of a program designed to incorporate physical activity into an academic subject area, are important, because they provide insight into an alternative method of teaching science that incorporates physical activity and facilitates learning of science inquiry skills and content.

## Conclusions

Our findings from these initial studies were consistent with an accumulating and impressive body of scientific evidence demonstrating that the integration of movement with learning helps to promote physical activity and supports academic achievement in school-age children. The children who participated in this project increased their physical activity in school, while simultaneously improving science achievement skills. The results of this study are well aligned with the recommendations from First Lady Michelle Obama's Let's Move campaign and the White House Task Force for Solving the Problem of Obesity within a Generation (2010), which endorse innovative strategies to incorporate movement and activity into diverse school and afterschool curricular activities. We hope that through the many positive experiences of the Active Science program, the children will continue to participate in daily physical activity and make healthy nutritional choices.

## Future Directions

The future plan involves the enhancement of the Active Science initiative, to further develop scalable frameworks and successful policies that help school and afterschool programs across the region and nationwide to incorporate movement concepts into diverse activities, thereby promoting improved health and academic success of school-age children.

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PROJECT REPORT

# The Real-World Connection:

## Incorporating Semester-Long Projects into Calculus II

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## Abstract

In order to increase student interest in mathematics and its connections to real applications, Roosevelt University began incorporating semester-long projects into its Calculus II (integral calculus) course. Different project topics are used each semester. Project creation has lead to opportunities for student involvement, including work as embedded tutors, undergraduate research projects, and opportunities for students to present posters and talks to a broader audience. In this report we describe the course design, improvements that have occurred over the years, and challenges to face.


## Background

Students can benefit from learning mathematics when the material is taught along with connections to realistic problems (Gravemeijer and Doorman 1999; Perrin 2007; Schreyer-Bennethum and Albright 2011). Most of the literature with examples of calculus projects falls into two categories. One is for a homogeneous student body with a common background, often in physics or engineering (Odenwald 2012; Andrew et al. 1996). The other focuses on short calculus skill-based projects where the main objective is to teach calculus rather than to model the interconnections between calculus and a real-world problem (Gaughan et al. 1991; Graver and Lardy 2001; Woods 1988). There are also papers with background ideas that have not yet been developed into projects, but which have a clear potential for development (Thomas 1977; Gablonsky 2005). There has been, however, some work done on small projects that can be used as units in part of a larger whole (Pfaff et al. 2011).

The approach for a homogeneous student body would not work for Roosevelt University. Unlike many research universities, Roosevelt has a wide variety of students who have spent years in college working their way up to a college calculus course. Some students start in developmental (non-college credit bearing) mathematics at Roosevelt and work their way up; some start at the College Algebra or Precalculus level. Some of them transfer from community colleges into Calculus I or II. Some of them have AP credit from high school and start in Calculus II. There are many first-generation college students, traditional college students, working adults, and transfer students. This presents a unique challenge to teach courses that are beneficial to all these very different groups of students.

Most students who take Calculus I and II major in Chemistry or Biology. There are also some Mathematics, Actuarial Science, Economics, and Computer Science majors, and the occasional student who is taking calculus but doesn't really need it. For all but the Mathematics and Actuarial Science majors, Calculus II is their terminal mathematics course.

The first inclination would be to try to separate these student groups into different calculus courses, but this is simply not feasible because of the total number of students taking this level of mathematics course. For example, enrollment in Calculus II varies between twenty and fifty students per semester, divided between two geographically distinct campuses in downtown Chicago and Schaumburg (about 30 miles apart).

In order to serve the varied student groups, a capstone experience which helps students to understand how very applicable calculus is to the world was created. This has been accomplished via the addition of a semester-long project that incorporates some civic issue. The project connects directly with a real-life problem. Because of this, students needed to learn the non-mathematical background. The project worked best when they focused on one major theme that was broken down into smaller, more manageable pieces.

The university has a history of supporting this type of effort. Beginning in the summer of 2005, Roosevelt University started to send teams of faculty in mathematics and the sciences to the Science Education for New Civic Engagements and Responsibilities (SENCER) summer institutes. "SENCER courses and programs strengthen student learning and interest in the sciences, technology, engineering, and mathematics by connecting course topics to issues of critical local, national, and global importance" (SENCER 2012), Through SENCER, there has been work done incorporating projects and activities into mathematics and science courses through their model course series (SENCER 2013). This series contains both examples of mathematics courses that incorporated real-world connections (Donnay 2008; Greenfield 2004) as well as science courses where as a part of the course students learn to understand mathematical and statistical models (Flaherty et al. 2008; Tibbetts 2003). Inspired by the summer institute, Roosevelt began to develop courses throughout the sciences that incorporate these ideals (Kim and Szpunar 2010; Wentz-Hunter 2009). In Spring 2010 the Calculus II course was SENCERized to include a semester-long research project designed by faculty (González-Arévalo and Pivarski 2010ab). To date, approximately two hundred students have taken this redesigned Calculus II course.

## Course Design and Student Involvement

Prior to 2010, Calculus II was a traditional four-credit integral calculus course covering the definite integral; applications of the integral, techniques of integration and elementary differential equations, indeterminate forms and improper integrals, and infinite series. Several modifications were made to allow for a class project. Part of the definite integral material was moved into Calculus I. The Physics applications for calculating center of mass and density were cut. Partial Fractions was trimmed to include only non-repeated linear factors with a brief discussion of other cases. This created the necessary space to incorporate the semester-long project. The group project involves a strong communication component with reflective journals due each week, written reports throughout the semester, and a poster presentation (see Tables 1 and 2). It also includes a library training session, labs with Maple/Mathematica, and class time for project work. Approximately ten percent of class time is dedicated to project-specific work, typically during whole or half class periods. For most semesters, students learned

**TABLE 1.** Project pieces for the first three projects.

| HIV/AIDS (%) | Gulf Oil Spill (%) | Guarantees (%) |
|---|---|---|
| | Estimating Areas/Sums (5) | Product/Guarantee (5) |
| HIV/AIDS Background (15) | Background (10) | Find Data (5) |
| Modeling Background (15) | Individual Areas/Sums (5) | Background (15) |
| Find Data (10) | Differential Equations (15) | Empirical Distributions (10) |
| Model Fitting (20) | Model Fitting (15) | Model Fitting (15) |
| Poster (15) | Poster (20) | Poster (20) |
| Paper (25) | Paper (20) | Paper (20) |
| Reflective Journals (10 percent of overall course grade rather than part of project grade) | Reflective Journals (10) | Reflective Journals (10) |

**Note:** First three projects. Project pieces and the relative work (in percent of project grade) of each portion. The project itself was worth between fifteen and twenty percent of the overall course grade.

**TABLE 2.** Project pieces for the last three projects.

| Gini Index (%) | Population (%) | Greenhouse Gas (%) |
|---|---|---|
| Find project (5) | Background (5) | Background (5) |
| Find Data (10) | Modeling Yeast (10) | Find Data (5) |
| Literature Review (5) | Model Realism (15) | Graphs and Concavity (15) |
| Empirical Distributions of Real Data (15) | Find Data (5) | Model Fitting (15) |
| Model Fitting (15) | Modeling Human Population (15) | Model Analysis (15) |
| Poster (20) | Poster (20) | Poster (15) |
| Paper (20) | Paper (20) | Paper (20) |
| Reflective Journals (10) | Reflective Journals (10) | Reflective Journals (10) |

**Note:** Last three projects. Project pieces and the relative work (in percent of project grade) of each portion. The project itself was worth between 15 and 20 percent of the overall course grade.

non-mathematical background by doing independent research after their library training session. In one of the semesters, one section had an outside speaker come in with a short presentation on how yeast data is collected. At the end of the semester there was discussion of the project and its civic implications in class, during the poster session, and in the students' reflective journals.

Each semester a project was done in groups of three to five students that rotated members for early parts and became fixed for later parts. New portions of the project were due approximately every two weeks. Main concepts were evaluated both in a group and individually through individual project par ts, group project parts,

**TABLE 3.** Mathematical and civic learning goals and the projects which contain them.

| Learning Goal | Projects Involving Goal |
|---|---|
| Use internet and library to independently research scientific background. | All |
| Understand challenges involved in finding a large, accurate dataset | All |
| Create models using differential equations | HIV/AIDS, Gulf Oil Spill, Population |
| Create models of functions based on understanding their derivative | Greenhouse Gas |
| Fit data to model | All |
| Understand connections between derivatives and integrals | All |
| Understand probability distributions | Gini Index, Guarantees |
| Interpret models correctly | All |
| Understand difference in interpolation and extrapolation | HIV/AIDS, Gulf Oil Spill, Population, Greenhouse Gas |
| Discuss the role of the government in regulating aspects of the topic | All |
| Describe trends in population growth and the impact on society | HIV/AIDS, Population |
| Evaluate whether a distribution is fair | Gini Index. Guarantees |
| Describe the breadth of an environmental issue and its impact on society | Gulf Oil Spill, Greenhouse Gas |
| Clearly describe mathematical concepts and civic issues in writing | All |
| Clearly describe mathematical concepts and civic issues orally | All |

**Note:** Each project involved a different topic; however, many of the overarching goals were the same.

and individual exam questions (González-Arévalo and Pivarski 2011).

Each semester has featured a different project (see Table 3): Spread of HIV/AIDS (Straffin 1993), Estimating the Deepwater Horizon Gulf Oil Spill (Pivarski 2011), Real Cost of Guarantees (Straffin 1993), Investigating Wealth Distribution Using the Gini Index (Urbina-Romero 2011), Population Growth (Balan 2012), and Greenhouse Gas Emissions (Castaldo 2012). Two of these, on HIV/AIDS and guarantees were modified from the MAA project book to match the semester-long format (Strafford 1993). Faculty created the oil spill and Gini index projects. In Summer 2011, two Roosevelt University undergraduates, Carina Balan and Jonathan Castaldo, joined in the design process. They studied the literature on projects in calculus, and they each designed a project for us to use: Population Growth, used in Spring 2012 and Greenhouse Gas Emissions, used in Fall 2012. Both students were funded as part of an NSF-STEP grant. Now every summer undergraduates work on the design of calculus projects as their own research projects (González-Arávalo and Pivarski 2012). By varying the project topics each semester, students are able to see a variety of uses of calculus over their time at the university. Previous semesters' posters hang in the hallways, and students in Calculus I are invited to the poster sessions where the Calculus II posters are presented. Additionally, because new topics are introduced each semester, there have been no instances of student material plagiarized from past semesters. However, when the course has been taught by adjunct faculty, they have had the option of reusing an older project to simplify their workload. This reuse has happened once so far.

Each of the different projects was designed to show students how one can understand the quantitative aspects of civic issues using models that rely on calculus for their construction. The calculus involved varied from project to project and included topics such as solutions of differential equations, probability distributions, and the connection between integrals and derivatives. Students learned about limitations of models due to the difficulty involved in finding reliable, uniformly collected data, propagation of round-off errors, and the difficulty of finding sufficiently large datasets. For example, in the population project students saw how a logistic can be used to easily fit a yeast population, while in human population their one hundred years of data involved too few generations to get a larger-scale logistic function. There, the best they could do was show a local linear or quadratic fit. This tied in well with the idea of approximation using Taylor polynomials, and led to a richer class discussion. They were able to discuss the difference between interpolation and extrapolation from data, along with the types of assumptions about future conditions that one needs in order to extrapolate. In some of their models, they also saw the need for increased mathematical and statistical sophistication beyond integral calculus.

In addition to the design process, students have been involved in the teaching as well. From the second semester onward there has been an embedded tutor in each section of the course. Often these undergraduate tutors have recently completed Calculus II, and they use this experience to cement their knowledge. The tutors also give the students in the course advice that, coming from a peer, has an increased sense of authenticity. The tutors are a great benefit for the technology component (use of Maple or Mathematica), as they can help answer questions during the lab days.

## Improvements to the Course

There have also been improvements in course content and organization. Originally, the reflective journals were worth ten percent of the overall course grade. These percentages were adjusted so that the reflective journals were worth ten percent of the project grade; this amounted to approximately two percent of the overall grade. The new percentages better reflected the relative amounts of effort involved in journaling versus other project work. Rotating group members for the early project parts had a significant impact on improving group dynamics. Moving the final paper deadline up by a week was also beneficial, since students didn't need to write at the same time that they were studying for their finals. This also helped faculty with their own time management in terms of grading. Although different topics were used each semester, each project helped to influence projects in subsequent semesters. In the first project on HIV/AIDS, the students demonstrated the ability to handle a more mathematically involved project than had been expected. This led us to design the projects involving higher-level mathematical skill. For three of the projects, students needed to fit data to logistic functions. In the first semester the limits of technology became evident, and faculty had to do the fit themselves. When the course was offered for the third time, students were using their knowledge of inflection points and limits to come up with their own fit. Although the material on sequences and series occurs late in the semester, the use of polynomial fits became a part of class discussions on Taylor polynomials. In this way, we were able to connect the project to this portion of the course while avoiding the need to know these topics earlier in the semester.

## Benefits to the University

The number of instructors who teach this type of course has increased steadily. Now forty percent of the full-time faculty in the department and an adjunct instructor are successful at teaching this course. As more projects are developed and implemented, the knowledge of what works has grown immensely. This allows for peer-mentoring among faculty.

Partly as a consequence of this course, the Math x-Position conference was developed and ran three times in Fall 2010, 2011, and 2012. The x-Position is a day-long event where students present posters of their projects, advanced students give talks, teams participate in a puzzle competition, and students learn from a career panel and keynote address. The calculus posters help to anchor the student research portion and increase interest in both students and the university community. There are typically about one hundred attendees at this event.

Students have also begun to present research work at conferences (Castaldo 2011, Balan 2011, Staszel 2012, Alexander 2012). Internally, Jonathan Castaldo, Carina Balan, Elizabeth Staszel, and Dana Alexander presented their project development work in short talks. Jonathan Castaldo and Carina Balan presented their research work at the Argonne Symposium in Fall 2011. In Fall 2012, Dana Alexander presented her work at Argonne. This level of student involvement is new for Roosevelt University.

Regardless of the specific topic involved, Calculus II with projects allows students to demonstrate their ability to synthesize mathematical and scientific knowledge via the projects themselves and exam questions on modeling. This is not a common aspect of traditional Calculus II courses. Because computations and interpreting models are different skills, students who have difficulty with timed computations have added opportunities to demonstrate their learning. For example, an exam question would give students a graph of project-related data and its model, and the students would describe the behavior of the model, including whether one can interpolate or extrapolate beyond the dataset. As most of the students in the course are science majors, this allows their grades to better reflect the type of calculus knowledge that they will be using in their future careers. Additionally, because individuals complete exam questions on the projects that were completed in groups, students have individual accountability for their work. These benefits occur for all of the projects regardless of topic.

## Challenges

Staffing is a challenge; however, our base of experienced instructors and embedded tutors has been growing with time. This course requires many things from the instructor: an interest in the non-mathematical subject matter, an investment in teaching a project-based course, a level of comfort with the calculus concepts involved, a level of comfort with technology, and most importantly a sufficient amount of time. The timing is key; this course involves more planning and organization than a traditional Calculus II course, and, due to the projects, the amount of grading is significantly increased. For an instructor with a large number of other duties, the demands of the time required to teach this course can be frustrating.

Given the variety of student backgrounds, this four-credit course could benefit from becoming a five-credit course. An additional hour of problem solving would benefit about ninety percent of the students in the course. Additionally, five credits would better reflect the amount of time and effort required of course instructors.

One happy challenge is due to increased enrollment in the course: the classrooms have fewer computer stations than students. This issue has been addressed by borrowing a few laptops from the sciences or having a few students bring their own computers.

Classroom space is also tricky. An ideal classroom has space for non-computer work as well as computer access. We have such a room on one campus, but not on the other.

## Student Reactions

Overall, students appreciated the connections between calculus and real-world problems, although they found the workload to be significant.

> *"After using differential equations to solve real world problems such as the Gulf spill, it got me thinking that mathematics can be used in a lot of different fields."*

> *"I came to understand what the point of calculus is and why it is applicable to everyday things. I had really no idea during Calculus I. "*

> *"I definitely learned more in this class than any other mathematics class so far, and even though I could have put more outside effort into learning the material, I feel like I still understand the basics of calc applications outside of class."*

Students who believed that their instructor was uninterested in the project were often dissatisfied with the project; this appeared to be unrelated to the specific topic involved. Additionally, a few of the students have expressed dissatisfaction with working in groups, typically due to personality conflicts within the group. Most of these students came to an understanding that even though their experience was uncomfortable, practicing interpersonal skills in a team environment will be useful in their future careers.

## Conclusion

Overall, Calculus II with semester-long projects has been both a challenging and rewarding course to teach. Instructors must dedicate sufficient time to communicate with the students both in class and in their grading. Instructors must handle issues of group dynamics that typically do not occur in a calculus course. In the future, we would like to incorporate projects into our Calculus I course, possibly on a smaller scale. In order to do so, we will need to have more faculty time available both for the design and for the implementation. It would be especially interesting thematically to have the Calculus I mini-projects lead into the next semester's Calculus II project; however, due to the number of transfer students, the Calculus I mini-project could not be an explicit requirement for completing the Calculus II project.

Similarly, Calculus II with semester-long projects has been both a challenging and rewarding course for students. Students leave the course with an enhanced appreciation for the connections between mathematics and other fields, rather than viewing them as isolated topics. Students also gain experience in using mathematics to more thoroughly model complicated issues that require quantitative knowledge. The projects involved were interesting to students regardless of topic and the use of real data gave students an increased sense of the difficulties involved in creating reliable and realistic models. Advanced students have benefited from working on project creation. Because of this, we plan to continue to create new projects and possibly to modify old projects with help from our students. Currently there are projects in the works on how acceleration affects head injuries and how one can create models predicting survival.

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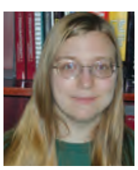

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PROJECT REPORT

# Service-Learning in an AIDS Course

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## Abstract

Service-learning has been incorporated into an AIDS course at Whittier College to enhance student learning and to help students make a positive contribution to the local community. Examples of projects include participation in AIDS Walk Los Angeles, World AIDS Day, Condom Crawl, design and distribute HIV/AIDS educational materials outside the campus cafeteria or on a campus website, or to design and administer an HIV/AIDS knowledge survey to people on and off the Whittier College campus. Students have rated AIDS Walk Los Angeles partnered with AIDS Project Los Angeles and World AIDS Day partnered with Whittier Rio Hondo AIDS Project as outstanding or above average. Also, students have reported on reflection papers learning about how HIV/AIDS impacts a diverse group of people and that they value the opportunity to fundraise for the organizations sponsoring these events and/or the opportunity to get tested as a means of taking personal responsibility in preventing the further spread of the disease. The service-learning projects have thus deepened the students' understanding of the disease and its impact on the local community.

## Introduction

Service-learning is being incorporated into an increasing variety of courses across the curriculum at many different colleges and universities (Chen et al. 2012, DeLaune et al. 2010, Feen-Calligan 2008, Osman 2011, Othmer and Sealfon 2010, Sutheimer 2008), to enhance student learning by making real-world connections to the theory learned in class (Esson et al. 2005, Prentice and Robinson 2010, Sutheimer 2008), and to make a positive impact in the local community (Esson et al. 2005, Osman 2011, Sutheimer 2008).

Whittier College, a liberal arts college in Southern California, established a pilot College and Community Program (CCP) in 2001 that has now expanded into the Center for Engagement with Communities (CEC), whose goal is to facilitate and encourage faculty to collaborate with community organizations and provide service-learning opportunities for their students. With encouragement from the director of the Whittier College CCP program, and with inspiration from attending the 2004 SENCER conference, I decided to add a service-learning component to an AIDS course I had first developed in 1999, which contained both the biological and cultural issues associated with this disease (Iimoto 2005).

In 2006, service-learning, via an internship at AIDS Project Los Angeles, was added as an option to a final project,. However, by 2010, service-learning was required of all students in the course, and this involved participation in a smaller scaled project such as AIDS Walk Los Angeles or World AIDS Day. Students have responded enthusiastically to the chance to contribute back to their community, and they agree that this has enhanced their learning in this course.

## Context for the Course

AIDS is one of many courses that meet the Connections II requirement of the Whittier College liberal education program; the goal of this requirement is for students to learn about a scientific topic in the context of societal issues, to stimulate their interest and enhance their understanding of science's relevance in the world. The course enrolls students from all disciplines who are typically in their junior or senior year of college. While most of the students are non-science majors, a significant minority are biology or chemistry majors. Thus, one of the challenges of teaching this course is to make the material accessible to students who have had few or no college level science courses prior to taking this class, while maintaining the interest of those students for whom the basic biological and chemical concepts are well understood. Because the service-learning component of the course gets the students actively engaged with the material, it helps to bridge this gap: both types of students, science and non-science, agree that this is a beneficial part of the course.

## Service-Learning Project Options

When the class has been taught in the fall semester, students have participated in either AIDS Walk Los Angeles (October) in partnership with AIDS Project Los Angeles (APLA) or World AIDS Day (December 1) in partnership with Whittier Rio Hondo AIDS Project (WR-HAP). Students who participated in AIDS Walk Los Angeles walked 10 km, wrote a two-page reflection paper, and raised a minimum of $50 for APLA. Students who commemorated World AIDS Day listened to speakers who are HIV+, participated in a candlelight ceremony to remember those who have died from HIV/AIDS, and had the opportunity to be tested for HIV. In addition, they wrote a two-page reflection paper and raised $50 for WRHAP.

When the course has been taught in the spring semester, students have chosen one of several possible projects, which included staffing an educational table outside the Whittier College cafeteria where students passed out HIV/AIDS brochures they had designed, or designed and displayed an HIV/AIDS poster board, or designed an AIDS educational web-link that was posted to the Whittier College health office website. In 2012, many students in the class partnered with WRHAP in a condom crawl to pass out condoms in the downtown Whittier bars, and two students designed an HIV/AIDS knowledge survey and interviewed fifty people each to test their knowledge of the disease.

Students who completed the condom crawl or knowledge survey were also required to write a two-page reflection paper. Because staffing the educational table or posting AIDS information on a website required significant research time, and putting together the posters, brochures, or websites was also time consuming, these students were not required to complete a reflection paper. Overall, it was important to provide students a choice of service-learning projects because these projects were conducted outside of official class time, and it gave students flexibility in case a student had a prior commitment on the date of a particular event.

## Assessment

Service-learning projects were assessed to determine if students' learning was enhanced and if they thought that doing the projects made a difference in the local community. Students were assessed based upon the reflection papers written in the fall of 2010 and upon a service-learning survey conducted in the fall of 2011.

Students who participated in AIDS Walk Los Angeles evaluated their experience as highly positive; in the fall of 2011, eighteen out of twenty students rated the AIDS Walk as either outstanding or above average (Table 1). Further examination of the evaluations indicated that the students thought that the service-learning project was most valuable in connecting the knowledge learned in the AIDS class to their service-learning project and connecting the service-learning experience to knowledge learned in other classes. Also, the project further helped students affirm the value and worth of individuals and communities and get involved with people who are culturally, ethnically, and socioeconomically different from themselves (an outcome also reported by Chen et al. (2012)).

In support of the above findings, fourteen out of twenty students who did the AIDS Walk in the fall of 2010 specifically commented in their reflection papers that the project made them realize that HIV/AIDS is a disease that impacts people from various ethnic, cultural, and socio-economic backgrounds and that people of all ages and backgrounds are able to come together to support those with HIV/AIDS (Table 2). Some specific comments include the following:

> "Many people think that they cannot get AIDS and that it is something that only affects low income communities, but when you see different ethnicities and people from different socio-economic backgrounds, it shows you that AIDS impacts all communities, not just the poor ones."

> "The thing that kept popping up in my head was the diversity of people that were there. There were little children and senior citizens, and what seemed like every race. The wide range of people made me think of all the people this virus has an impact on and in the sea of people walking, it's hard to tell who's infected."

Students also valued this service-learning project because it was the chance to give back to the community and support a worthy cause (thirteen out of twenty students in 2010 specifically wrote about this in their reflection papers as seen in Table 2). For one student, the event changed his mind about people with HIV/AIDS. He wrote the following:

> "I'm really thankful for the opportunity to be a part of the walk. It really changed my view of the disease, and the lifestyles. I had a very negative view of people who had AIDS due to media, and the things I've heard. But, the walk helped me realize that having AIDS doesn't make you a bad person. It just means somehow you got infected with something."

Like the students who did the AIDS Walk, students were highly positive about their World AIDS Day experience, with all sixteen students in the fall of 2011 rating the event as outstanding or above average (Table 1). In the reflection papers from the fall of 2010, students noted the diversity of people impacted by HIV/AIDS and those there to support them (five out of thirteen in Table 2). They also discussed what they learned: the importance of testing and prevention, how the medications have helped

**TABLE 1.** Survey on Service Learning Experience (Fall 2011).

| | Excellent | Above Average | Average | Below Average | Never Use Again |
|---|---|---|---|---|---|
| AIDS Walk Los Angeles | 13 | 5 | 2 | 0 | 0 |
| World AIDS Day | 11 | 5 | 0 | 0 | 0 |

**TABLE 2.** Key Themes in Reflection Papers (Fall 2010).

| AIDS Walk Los Angeles (n= 20) | World AIDS Day (n=13) |
|---|---|
| 1. Diversity of People Impacted (14)<br>2. Chance to Give Back to Community (13) | 1. Learning Experience (10)<br>2. Diversity of People Impacted (5) |

people live longer lives, and that being out in the community made them realize that the disease was not just an abstract concept, but that it is in the Whittier community (ten out of thirteen in Table 2). One student wrote in her reflection paper the following comment.

> "One of the biggest realizations I had from this service learning project was that AIDS really is invisible.... Many people might know what AIDS is but they do not realize how close it is to them…. I live in Whittier myself, and this service learning project helped me to better understand in my mind and place into perspective that AIDS does affect many within my community and that we all need to try to have a greater awareness."

Finally, for many students the best part of this service-learning project was the opportunity to get tested as a means to know their status and thus do their part in preventing the spread of HIV.

Students who participated in the condom crawl in spring 2012 passed out condoms provided by WRHAP in the Whittier downtown bars and briefly educated everyone about practicing safer sex. In their reflection papers, several students commented that they were ambivalent about the event ahead of time, but once the group started walking through the bars and they realized that most customers appreciated the free condoms and the message that the students were trying to convey, their attitudes about the project changed and it became fun and rewarding. Also, the two students who designed an HIV/AIDS survey to ascertain the general population's knowledge of HIV/AIDS reported that survey participants were eager to learn if they had answered the questions correctly. The students also reported great satisfaction in their ability to explain the answers to the questions and thus educate more people about the disease.

Finally, as previously mentioned, service-learning was an option to two class projects from 2006-2009. During this time period, students could do a semester-long internship at AIDS Project Los Angeles in their case management program; students worked with a licensed social worker to do client intakes, discuss possible ways that APLA could help clients, call current clients to follow up with them and determine if they needed any more services from APLA, answer phones, and file paperwork. Students who participated in the internship were required to do a power point presentation to the class to report on their experience there. Students reported great satisfaction with the opportunity to work with people with the disease because it helped make the theory learned in class real to them and they appreciated the opportunity to apply the knowledge learned in class on a day-to-day basis in their internship.

## Lessons Learned

A few students in the fall of 2010 complained about being required to raise $100 for the sponsoring organization. The purpose for this part of the project was to encourage students to talk to others about HIV/AIDS and to provide financial support for organizations working with people with HIV/AIDS. Several students raised more money than the minimum amount and were appreciative of the opportunity to help these organizations in this manner. However, I wanted to be sensitive to the student concerns, and in the fall of 2011, I reduced the amount of money that needed to be fundraised for the project from $100 to $50.

Another lesson learned is that while interning in the case management program at APLA is likely the most meaningful project in terms of connecting classroom learning to community service, the requirements for this project are too demanding for most students. APLA requires a time commitment of six to eight hours per week for twelve weeks, and furthermore, since the internship site is located twenty miles from Whittier College, a student must own a car to travel to the internship site. As a consequence, between 2006 and 2009 only five students in two out of four possible semesters chose this service-learning project as an option to two class projects. Since I started requiring the service-learning projects in 2010, I have continued to offer the APLA internship as an option to fulfill the service-learning project and in lieu of an in-class group debate. However, no student in the last two years has chosen to do the APLA internship. While ideally it would be great to have every student participate in an internship at one of several AIDS organizations in Southern California, it is not a practical idea at this time.

## Conclusion

Adding the service-learning component to the AIDS course has helped students connect the information learned in class to the real world, in that students have recognized the diversity of people impacted, and the presence of AIDS in their local community, while also having the opportunity to get tested and having the information related to testing, prevention, and medications be reinforced in a setting outside the classroom. Students have also made a positive contribution to the community by spreading awareness through educational materials or passing out condoms, and by raising money to support AIDS organizations. AIDS Walk Los Angeles and World AIDS Day were most successful in connecting students to the local AIDS community and were rated highly by the students. The Condom Crawl and the AIDS knowledge survey also elicited positive responses from the students. Finally, while the students who did the AIDS education posters, brochures, or websites on campus did not write reflection papers, the quality of most groups' work indicated effort and passion for educating others about HIV/AIDS.

## About the Author

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PROJECT REPORT

# "Putting the Backbone into Interdisciplinary Learning"

## An Initial Report


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## Introduction

The overarching goal of the academic program at the United States Military Academy (USMA), West Point, NY, is that "Graduates anticipate and respond effectively to the uncertainties of a changing technological, social, political, and economic world (USMA, 9)." Implied in this goal is the mission of developing highly adaptive learners capable of solving complex and challenging problems. General Martin Dempsey, Chairman of the US Joint Chiefs of Staff, reiterated that the mission of the military's leader development programs was to produce leaders who can respond rapidly to an ever-evolving threat and the technological, social, political, environmental, and economic complexities it creates.

> "Our leader development programs must produce and reward leaders who are inquisitive, creative and adaptable.... Development of adaptive leaders who are comfortable operating in ambiguity and complexity will increasingly be our competitive advantage against future threats to our Nation." (Dempsey, 2011, p. 26)

Many of today's complex problems, such as those involving renewable energy, climate change, resource sustainability, terrorism, and health care availability, require solutions involving more than one discipline. Project Kaleidoscope's Summary Report: "What Works in Facilitating Interdisciplinary Learning in Science and Mathematics" signaled this emerging trend in higher education by voicing the belief that "interdisciplinary learning is a twenty-first-century imperative (USMA, 1)." In order to ensure that its next generation of leaders are prepared for this environment, the Academy needs to adapt its academic program to this new dynamic.

Cadets at the USMA have been engaged in interdisciplinary learning within their academic majors for a number of years; however, recently Brigadier General Timothy Trainor, the Dean of the Academic Board, recognized that more needed to be done, especially within the Academy's core curriculum. He directed the Academic Excellence Committee (AEC) to investigate ways to promote interdisciplinary collaboration between academic departments with a special emphasis in the core curriculum. The core curriculum consists of thirty courses that every student must take, including a three course engineering sequence. This core program provides an ideal opportunity to have students engage in problem solving from multiple perspectives.

## The Next Steps

Since almost everyone on the AEC had a different interpretation of "interdisciplinary learning," the AEC's first challenge was to agree on what these two words meant. After research and much discussion, we decided to use the following definitions to support our understanding of interdisciplinary learning:

1. **Interdisciplinary** involves the integration and synthesis of ideas and methods from two or more disciplines.
2. **Multidisciplinary** involves two or more disciplines where each makes a separate contribution to a defined project.
3. **Disciplinary** involves one discipline.

Using these definitions, we found excellent examples of interdisciplinary work at the Academy, but most involved academic major programs and research projects for junior and senior students. Although there were a few attempts at interdisciplinary learning and collaboration within the core curriculum, these efforts were isolated, small in scope and complexity, and unsustainable due to the workload required by the faculty. We also benchmarked our efforts against many other colleges that had reputable programs involving interdisciplinary learning. Again, we found numerous excellent examples, but these examples were generally not pervasive throughout students' four-year collegiate experiences.

While researching interdisciplinary programs at other schools, we found numerous challenges in establishing interdisciplinary efforts at the undergraduate level to include both faculty and curriculum/culture challenges.

1. **Faculty challenges:**
   a. It is not natural for faculty to cross boundaries into other disciplines.
   b. Collaboration between disciplines requires a significant amount of time.
   c. Familiarity with colleagues in other departments is often minimal.
   d. Junior faculty in particular are not ready to engage in interdisciplinary efforts.
   e. Finding resources is always a challenge.

2. **Curriculum/cultural challenges:**
   a. Maintaining requirements that support the Accreditation Board for Engineering and Technology (ABET) / majors programs.
   b. Balance between disciplinary focus and interdisciplinary relationships.
   c. Dislike for eliminating/changing course content to make room for interdisciplinary topics or lessons.
   d. Student cynicism.

Considering these and many other challenges, we determined that a successful interdisciplinary effort at West Point must:

1. Support the Academy's mission and academic goal.
2. Be easy to sustain.
3. Require a minimal infusion of resources.
4. Not jeopardize accreditation, although we must be willing to assume some risk to initiate.
5. Include a thorough assessment plan utilizing quantitative and qualitative means.

We kept the above challenges and requirements in mind as we progressed on our journey and made significant efforts to address them candidly, in order to promote transparency among faculty and to acknowledge that this was a paradigm shift that would require give and take from all participants. These next tasks soon became clear, albeit overwhelming:

1. Build on what we currently do. Encourage core programs to have students undertake the analysis of a problem, commensurate with their stage of education at the Academy, from more than one disciplinary vantage point.

2. Determine how we can foster a culture of interdisciplinary education in the core courses.
3. Begin discussions of interdisciplinary efforts in the monthly freshman program director meetings.
4. Identify current real-world problems and issues and then find intersections among disciplines.
5. Find out more about the Science Education for New Civic Engagements and Responsibilities (SENCER) organization and its annual Summer Institute in order to acquire the skill set necessary to develop enhanced interdisciplinary efforts.
6. Submit a proposal and form a team to attend the Academy's first SENCER Summer Institute (summer of 2011).
7. Motivate / educate faculty using the SENCER Summer Institute experience.
8. Modify / build summer and yearlong faculty development programs focusing on interdisciplinary efforts.
9. Scaffold our interdisciplinary efforts so that students are exposed to more as they progress through their forty-seven month experience.

In order to learn more about SENCER and to help us prioritize/strategize, we invited Dr. Barbara Tewksbury, a Senior SENCER Leader Fellow, to speak to faculty at West Point. She spoke to about fifty senior faculty and to say that these faculty departed her presentation extremely motivated about embarking on an interdisciplinary initiative would be an understatement. She taught us many things, including the importance of generating support from within the Academy and finding a common theme that all disciplines can rally around.

To build consensus in the community we presented our ideas to our Dean and Vice-Dean for Education in January 2011. As a result, we received both additional guidance and support, support which resulted in sending a team of six senior faculty – including one representative from our Dean's office – to the SENCER Summer Institute at Butler University. Following the meeting with our Dean and Vice-Dean, we presented our findings and projected plan to our Faculty Council. It was during this meeting that we collected ideas for the common theme of the interdisciplinary problem we would study. After soliciting several ideas, our Faculty Council voted to establish the central theme of *energy*.

Energy is a critical problem for the Nation as well as for the Army, and the Pentagon is fully committed to shrinking its energy footprint. We knew we could appropriately scope the topic to fit seamlessly into a number of subject areas. We further refined this topic to address the challenge of energy security at Forward Operating Bases (FOBs), which are secure military positions units from which combat operations are conducted. Sustaining these FOBs with energy has proven a difficult resource challenge for the Army and has resulted indirectly in significant loss of life, making it an extremely relevant civic problem for the students. FOBs are not only relevant to the future careers of our students, but establishing this focus allowed us to scope the very broad energy theme to a common problem of workable size. To understand and meet this challenge, multiple perspectives are required; at the same time, it impacts combat readiness and effectiveness. This challenge is also extremely relevant for students, and it relates to current battlefield operations in which they will soon find themselves.

The SENCER Summer Institute at Butler University provided us an opportunity to gather with a community of educators, administrators, students, and community leaders to consider how best to engage students in the sciences, technology, engineering, mathematics, and the civic issues in which they play an integral role. These real-world problems provided a nexus for interdisciplinary collaboration, and the Institute imparted the key skills necessary for us to design and implement our interdisciplinary effort to help solve our complex problem. The group that attended the Institute returned to West Point and formed the heart of a new committee which is now called the Core Interdisciplinary Team (CIT). The Institute helped to galvanize and energize the interdisciplinary effort within our core curriculum for the CIT, an effort which consisted of forming an institutional program that injected energy-related topics into fifteen core courses spanning several disciplines, beginning the following academic year.

Approximately 1100 students in the Class of 2016 are receiving an exposure to energy security topics and challenges within courses like Chemistry, Math, English, Psychology, and Information Technology. Exposure in their freshman year will lead to application the following year in Math, Physics, Environmental Engineering, Economics, and Political Science courses. The CIT then drafted the following goal for our interdisciplinary effort, which was nested within both West Point's overarching academic goal and the Academy's mission:

> Develop leaders of character who are able to use the knowledge, skills, and perspectives of multiple disciplines to make informed decisions regarding energy demand, efficiency, alternate sources, and accountability to enhance energy security.

We also developed a set of student learning outcomes specific to this effort. Each of our students would:

1. Understand the fundamental issues and scientific principles underlying energy consumption, reduction, and production as they apply individually and socially.
2. Construct and utilize mathematical models to facilitate analysis and understanding of energy consumption, reduction, and production at the individual and organization levels of use.
3. Increase personal and professional (civic) responsibility for energy use in the Army by understanding and applying theories of individual, group, and societal behavior in the context of change.
4. Communicate orally and in writing, ideas, issues, and arguments concerning energy consumption, reduction, and production as they apply individually and socially.
5. Develop an interdisciplinary perspective that supports knowledge transfer across disciplinary boundaries and supports innovative solutions to complex energy problems/projects.

Throughout our planning we kept both the faculty and the institution's leadership involved in our work through a series of meetings and presentations culminating in an executive meeting with all of the Department Heads, the Commandant of Cadets, and the Dean.

## The Backbone of the Interdisciplinary Effort—"the Spine"

Building support among the faculty and Academy leadership was relatively easy compared to the actual process of determining how to create the interdisciplinary context. We were left pondering the words of Julie Klein (2010) as we began our effort.

> "Institutions that embrace interdisciplinary collaboration are most likely to succeed in the new millennium.... Interdisciplinary collaboration is quite a mantra. But despite the desire for this, many are uncertain how to do it, particularly how to do it effectively."

We knew we wanted *it*, but we just didn't know exactly what *it* was. Having our topic of energy was exciting and motivating for us, but achieving synergy between courses in the core still seemed to be elusive. We quickly realized that of the five courses to be involved in the interdisciplinary effort, Math, Chemistry, English, Psychology, and Information Technology, the courses which we initially felt had the most flexibility were Math and Chemistry, as there was an overwhelming abundance of topics we could relate to energy. Thus we created an interdisciplinary "spine" of topics for the freshman class (Chemistry and Math) and then another "spine" for sophomore year (Physics and Math).

The CIT's intent throughout its planning has been and continues to be to minimize change and the reduction of course content. We aim instead to utilize energy applications in lieu of the many other applications, some of which were outdated, in the curricula of the courses. Using "Energy on the FOB" as the focus, the Chemistry and Math course leadership scoured through their courses' curricula and identified opportunities to replace examples, problems, and vignettes with FOB-related versions, with minimal expenditure of resources. These were identified and placed on a timeline which resembles a spine (Figure 1). This Figure is included here to give the reader a graphical sense of the origination of the term "spine" for our effort; note that the blue stars represent Math opportunities while the red Xs represent opportunities in Chemistry.

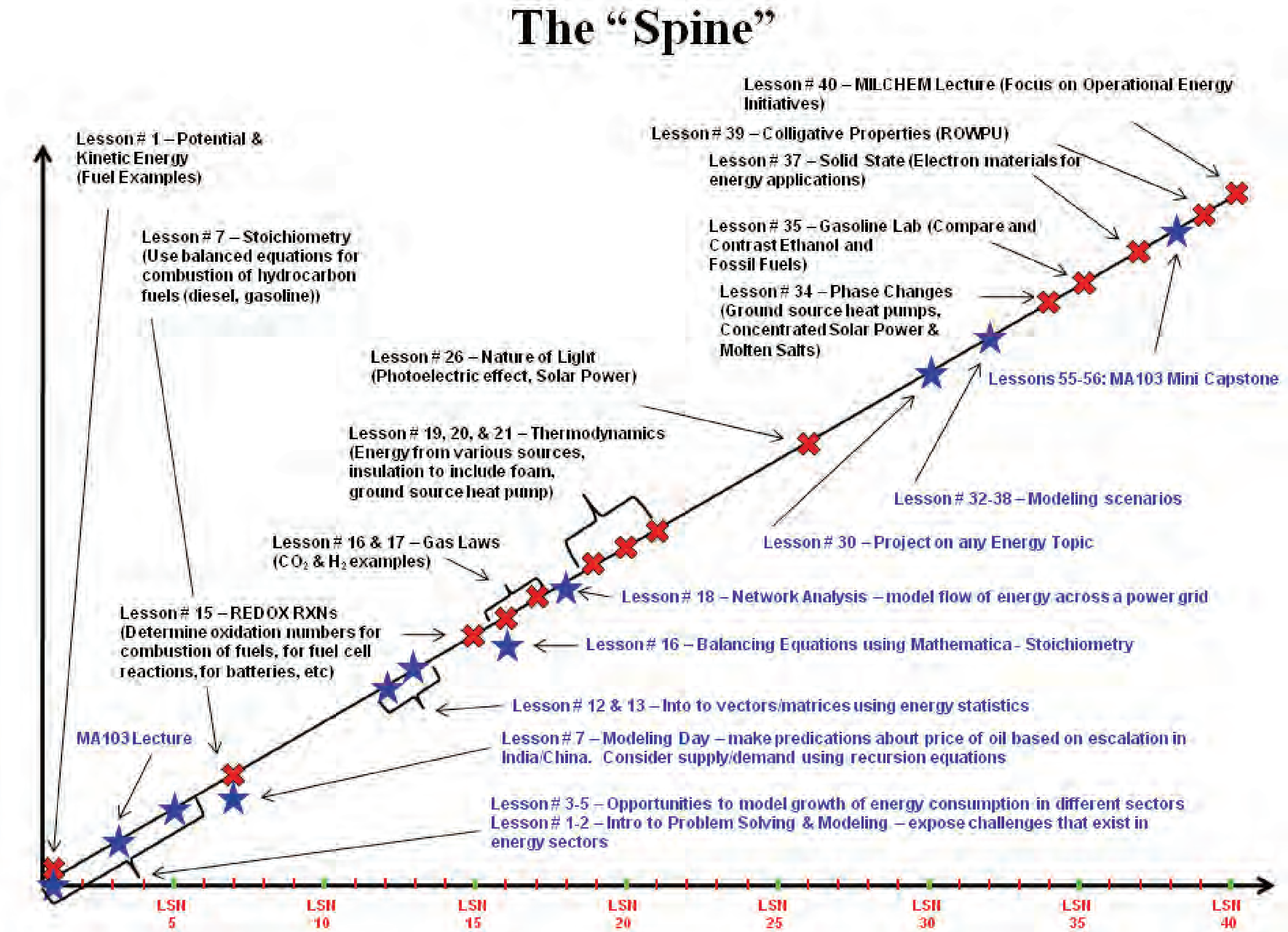


**FIGURE 1.** The Freshman Spine (Chemistry and Math)

The spine provided the Chemistry and Math courses with a visualization of where the possible intersections between the courses occurred and where synergies could be enhanced with coordination. We learned that we did not have enough of an understanding of each other's curriculum to maximize these intersections. In order to mitigate this roadblock the instructors met a number of times to explain their courses in detail, in order to facilitate further planning and coordination. These meetings were extremely fruitful and unveiled numerous opportunities where the courses could achieve great synergy. An example of this synergy is the use of reverse osmosis of local sources of water to provide potable water for FOBs. Because of the high demand for water at the FOBs, significant resources are needed to truck bottled and bulk water, something which exposes soldiers to dangers inherent in convoy operations. Chemistry studies this topic using osmotic pressure, the underlying scientific concept in reverse osmosis, while Math can use mathematical modeling and data analysis to assess the generator load and corresponding fuel use versus water gained when operating such reverse osmosis equipment.

Once Chemistry and Math completed the spine, other courses were able to determine opportunities where they could contribute and enter into the energy narrative and connect disciplines wherever applicable to promote knowledge transfer. English, for example, capitalized on a short essay students wrote for their Math class on how the mathematical modeling process was an important component in addressing NET ZERO energy solutions, by revisiting the essay with students in their English classes. West Point was recently selected as a NET ZERO Energy Installation, which means it has a goal to produce as much energy on site as it uses over the course of a year by 2020. This is a tremendous challenge that will not only require a culture change in how our students value energy security and sustainability, but will also require faculty to change how they teach.

Students were required to both use revision and editing techniques to improve their existing papers, and they were also asked to expand upon the original essay by assessing the importance of the humanities and at least one other academic discipline or field of study in raising awareness about energy consumption and developing solutions to promote sustainable use of energy. In addition to this prescribed course-wide assignment, students also performed literature reviews on energy-related topics, and other energy-related debates, writings, and endeavors.

Psychology also developed students to become more ethical and effective leaders with regard to energy decisions through a scientific understanding of human behavior. In one example, they expanded on a problem provided to students in Math class which required them to determine the best energy source with which to equip soldiers in lieu of conventional (i.e. AA or AAA) batteries, given supporting statistics. Psychology's extension of this prompt noted the disparity between soldiers' attitudes and behaviors, noting that soldiers continued to resist adopting the new technology despite the mathematical evidence indicating that the alternative battery source was superior to conventional battery types currently in use. Using the Theory of Planned Behavior, students were asked to develop a successful fielding plan incorporating their understanding of the three key aspects of persuasion (the communicator, the message, and the audience) to influence soldier attitudes. These questions not only addressed material taught in both courses, but arguably also their tie-in broadened student perception of the inherent interdisciplinary complexities beneath otherwise seemingly straightforward problems.

West Point's required and newly revised general education Information Technology (IT) course is taught to the entire freshman class, with half of the class taking it each semester. The first half of the course is an introduction to basic programming concepts and techniques using the Python programming language. The second half encompasses information technology topics such as computer hardware and software, security and privacy, and problem-solving using various learned technologies. The course also explores intellectual property and ethics as they apply to IT.

Although not as closely tied to the topic of energy as the Chemistry and Mathematics courses, the IT course has three different areas in which it explores topics related to the interdisciplinary energy initiative. In the security and privacy block of instruction, as a global example of the contemporary issues being faced, the 2010 Stuxnet virus is studied and class discussions consider the potential impacts of this type of event on the energy infrastructure in the United States. In another two-hour problem-solving lab, students are provided the raw data of the amounts of energy used by their dorms (barracks) over a period of several weeks. They learn new Microsoft Excel skills as they extract usable information that can then be graphed and placed in a report. Students are able to identify and observe the patterns of energy consumption over time, how class periods and study periods affect the graph peaks, and what other conclusions they can draw on how energy is consumed and could be conserved in their living areas. The third major topic covered is during the course's Technology Tour, when all students view demonstrations on how their IT course prepares them to understand advanced concepts in the areas of Computer Science, Information Technology, and Electrical Engineering. In the demonstration by the department's Photonic Research Center, students are shown a view from space of the electrical light footprint of the planet and how the evolution of new light bulbs and other technologies is helping to decrease that footprint and save money across the planet. Although these experiences are not explicitly tied to those covered in the Chemistry and Mathematics courses, students are reminded during the lessons that this IT material supports their overall understanding of the energy topic.

In the beginning of the 2012 fall semester, the CIT presented the planned interdisciplinary program to approximately 100 faculty scheduled to teach in the five courses involved in the program. We outlined the strategic picture and motivation for our engagement in this effort, addressing the questions: why interdisciplinary, why energy, why now, and why at West Point. The presentation was a success in that it "set the hook" for our faculty; many told us afterwards how appreciative they were and how much they were looking forward to teaching in this endeavor.

Next came the harder sell, to our students. The week following the faculty briefing, we attempted to "set the hook" with approximately 2000 freshman and sophomore students. We invited two guest speakers to speak in three separate presentations to the freshman, the sophomores, and then to the faculty. One of the presenters was a senior civilian leader (two star military equivalent) who has played a significant role in developing the Army's strategy with respect to energy for the future. Needless to say, he understands its importance and is a strong supporter of interdisciplinary study. The second speaker was recently redeployed from a tour in Afghanistan as a company commander in a forward support battalion and was responsible for providing logistical support to many forward deployed units. In joint presentations, our two speakers highlighted the strategic importance and concerns of energy security, and then gave a tactical introduction, including the first-hand description of experiences in managing the logistical complexities of day-to-day operations at FOBs in Afghanistan. Student written and verbal feedback from these presentations verified that they captured their interest and attention, and motivated them for future study and for their leadership as an Army officer in this critical area.

## Assessing the Interdisciplinary Effort

We will continue to grow and develop this initiative through the use of a comprehensive assessment plan—which itself is a work in progress as we generate new ideas to implement and evaluate. Summative evaluations in the form of exam questions and essay assignments such as the English requirement described above are useful in measuring content understanding and increased complexity of thought on the topic of energy. Equally important to this effort are students' subjective perceptions and attitudes about their expectations and progress in this endeavor. Collecting this information allows faculty to adjust their instruction based on direct feedback, and also encourages students to take greater responsibility for their learning.

To address this latter objective we are employing an adapted version of the SENCER Student Assessment of Learning Gains (SENCER-SALG), an on-line, open-use instrument that is aligned with the educational goals of SENCER (Jordan, 2012). Our pre- and post-versions of the SENCER-SALG address skill development, learning integration, content knowledge, and interest in energy and civic engagement thereof. To establish a baseline we employed a post-test to the Class of 2015 at the conclusion of the 2012 academic year that will allow comparison to the Class of 2016, the first USMA class to participate in this new curriculum. The Class of 2016 will be surveyed a total of three times in the first year: a pre-test that was administered prior to beginning classes, as well as mid-year and end-of-year assessments. Our initial analysis will explore differences between the two classes at the end of their respective freshman years, as well as changes within students who received the new curriculum over the course of the 2013 academic year.

We continue to refine our overarching assessment plan to ensure that it is both comprehensive and formative. Along with SENCER-SALG survey data, we are also utilizing feedback from faculty and student focus groups, qualitative analyses of student essays, exam results, and evaluation of the capstone project that will occur at the end of the second semester, to evaluate the effectiveness of our interdisciplinary effort, make improvements, and generate new ideas. While we do not yet have any definitive analysis of the many assessments we have already collected, it is clear that our interdisciplinary work is generating excitement both within the student body and more importantly within the faculty who are collaborating in a manner never before seen at the Academy. The faculty are in fact modeling the same behavior and adaptability we wish to instill in our graduates to prepare them to be problem-solvers in this rapidly changing world.

## About the Authors

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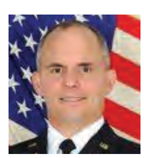

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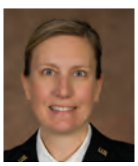

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RESEARCH ARTICLE

# What Biology Concepts are Important in General Education?:

## A Survey of Faculty Members and Students

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## Abstract

What are the most important concepts to teach in an introductory non-majors biology course? A survey including 17 core biological topics was compiled and then distributed to Life Science professors at Brigham Young University and Utah Valley University to identify the most critical topics to be included in such a course. Upon the completion of this initial distribution, the survey was then given to students in an introductory non-majors biology course as well as an introductory biology course for science majors. This study revealed that although there are no differences among professors from separate universities, there are significant discrepancies among what teachers and students deem to teach is such a course in the subjects that teachers and students deem the most important in such a course. The students ranked evolution, ecology, and scientific reasoning much lower in importance compared to the faculty. This ranking reveals that students do not understand some of the key points of basic biological concepts in the bigger world of biology. Failure to instill the importance of such critical topics greatly inhibits the establishment of a well-informed citizen scientist among the general populace.

## Introduction

There has been a nation-wide push to develop learning outcomes for all university courses, in order to set a standard for what students should know upon completion of a course. However, as noted in the literature, college students coming out of introductory courses show a surprising lack of understanding (NRC, 1997) about basic biology concepts and principles such as evolution (Alters and Nelson, 2002) and ecology (Mason, 1992) and even significant chronic misconceptions about key ideas such as the importance of scientific reasoning. In order to combat this rising phenomenon, some investigators (Bransford, Brown, and Corking, 1999) have reported that students are more likely to develop usable knowledge if teachers give repeated feedback on student understanding. It is also deemed important for teachers to allow students time, both in laboratory and lecture, for principles to stimulate understanding and creative thinking (Crow, 2004). However, even when feedback is provided and students are given time to ponder the principles, it has been repeatedly noted that many students still do not understand why certain topics are included in a course. Students often consider them "boring" or unrelated to their career path. Hence, the intent of the present study is to evaluate what themes in biology are important to learn, from both a student and a faculty point of view, so that desirable course outcomes can be established and student perceptions of these outcomes can be evaluated.

A survey was conducted in which each participant (student and faculty member) was asked to rank seventeen themes in biology from the most important to the least important. These themes were chosen by the authors of the survey, with input given by other life science professors involved in teaching introductory biology courses at Brigham Young University (BYU) and Utah Valley University (UVU). Based on a sampling of introductory biology textbooks most frequently used at the two institutions (Campbell et al., 2008; Starr and Taggert, 2008; Raven et al., 2008), the seventeen topics were key themes covered in all three of the introductory biology textbooks reviewed. This survey revealed surprising discrepancies in the learning outcomes expected by students and by teachers. The current results reflect the outcome for students at only a single university and the life science faculty of two universities, but it would be interesting to learn whether administering the survey at multiple institutions would produce a similar outcome.

## Methods

This survey was sent to BYU life science professors and UVU life science professors and asked the professors to rank a list of seventeen biological concepts from the most to the least important for non-majors in an introductory biology course. Professors also included their demographic information on this survey (education, current job, subject taught, etc.).

Following this initial distribution, the survey was then distributed to students who were in Dr. Gary M. Booth's non-majors Biology 100 class the previous semester and students who were just completing Biology 120, an introductory biology course for science majors at BYU. The survey was taken at the end of the semester, after the course curriculum was completed. Students also included their demographic information (year in school, current course, etc.). There were 66/105 non-major students, 352/621 major students, and 64/86 faculty participants in the study. (The numerator is the number of respondents compared to the denominator, the population surveyed.) A comparison among non-major biology students, biology major students, and professors was then conducted to determine the rankings of each group and compare differences. All of the returned surveys were completely filled out, i.e. there were no missing data.

The courses for majors and non-majors were taught in a similar fashion. They were both typical classroom settings with lectures and exams, and neither class involved research or lab work. Both major and non-major classes that were surveyed were composed primarily of freshmen.

## Measures

The survey contained seventeen concepts to be ranked from one (most important) to seventeen (least important). These concepts were chosen based on topics traditionally included in introductory biology textbooks (Campbell et al., 2008; Starr and Taggert, 2008; Raven et al., 2008). These themes were:

- Scientific Reasoning/Method
- The Cell
- Evolution
- Cell Division
- Biological Molecules
- The Central Dogma
- Mendelian Genetics
- Ecology
- Bioenergetics (cellular respiration)
- Photosynthesis
- Metabolism and Enzymes
- History of Science
- Fundamentals of Chemistry

- Plant Reproduction
- Embryonic Development
- Immunology
- Viruses

*A copy of the survey can be found in Appendix A.*

## Statistical Analysis

A one-way Analysis of Variance Between Groups (ANOVA) was used to analyze the mean rankings of each of the seventeen concepts for professors, non-major, and major students. When there were significant differences (significant F test), an LSD (least significant difference) post hoc test was conducted to find where the differences were. An LSD test can be used when significance is found in the ANOVA, and LSD provides the most power. Significance was $\alpha \leq 0.05$.

## Results and Discussion

The three concepts most frequently ranked as important by professors were: Scientific Reasoning (3.78 average ranking), The Cell (4.11), and Evolution (5.38). The bottom three concepts were Viruses (13.95), Immunology (13.52), and Embryonic Development (12.95). These data differed significantly from those of the non-majors (Biology 100) and majors (PDBio 120), who ranked (on average) the following as the top three concepts: The Cell (3.15 non-majors, 3.32 majors), Cell Division (5.82

**TABLE 1.** Summary of average rankings among professors, non-major, and major students and p values for differences in average rankings for seventeen biology concepts among professors, non-major, and major students based on a one-way ANOVA.

| Concept | Faculty Average Ranking | Non-major Students Average Ranking | Major Students Average Ranking | p value |
|---|---|---|---|---|
| Evolution | 5.38 | 11.11 | 11.14 | 0.0001* |
| Fundamentals of Chemistry | 10.25 | 10.40 | 9.43 | 0.248 |
| The Cell | 4.11 | 3.15 | 3.32 | 0.116 |
| Bioenergetics | 8.63 | 9.38 | 8.58 | 0.348 |
| The Central Dogma | 7.67 | 6.26 | 7.34 | 0.231 |
| Immunology | 13.52 | 9.71 | 11.51 | 0.0001* |
| Viruses | 13.95 | 9.80 | 11.05 | 0.0001* |
| Cell Division | 7.27 | 5.82 | 5.95 | 0.042* |
| Mendelian Genetics | 7.83 | 8.14 | 9.70 | 0.0001* |
| Metabolism and Enzymes | 9.14 | 7.83 | 7.96 | 0.043* |
| Photosynthesis | 8.84 | 8.36 | 7.74 | 0.076 |
| Plant Reproduction | 12.38 | 12.05 | 11.28 | 0.059 |
| Biological Molecules | 7.83 | 5.50 | 5.37 | 0.0001* |
| Embryonic Development | 12.94 | 9.68 | 10.68 | 0.0001* |
| History of Science | 9.91 | 13.15 | 11.76 | 0.002* |
| Scientific Reasoning | 3.78 | 9.44 | 6.56 | 0.0001* |
| Ecology | 8.03 | 12.00 | 12.17 | 0.0001* |

*Statistically significant $p \leq 0.05$

**TABLE 2.**
Summary of average rankings listed from greatest to least importance as rated by faculty.

| Concept | Faculty Average Ranking |
|---|---|
| Scientific Reasoning | 3.78 |
| The Cell | 4.11 |
| Evolution | 5.38 |
| Cell Division | 7.27 |
| The Central Dogma | 7.67 |
| Biological Macromolecules | 7.83 |
| Mendelian Genetics | 7.83 |
| Ecology | 8.03 |
| Bioenergetics | 8.63 |
| Photosynthesis | 8.84 |
| Metabolism and Enzymes | 9.14 |
| History of Science | 9.91 |
| Fundamentals of Chemistry | 10.25 |
| Plant Reproduction | 12.38 |
| Embryonic Development | 12.94 |
| Immunology | 13.52 |
| Viruses | 13.95 |

**TABLE 3.**
Summary of average rankings for seventeen biology concepts listed from greatest to least importance as rated by non-major students.

| Concept | Non-major Students Average Ranking |
|---|---|
| The Cell | 3.15 |
| Biological Molecules | 5.50 |
| Cell Division | 5.82 |
| The Central Dogma | 6.26 |
| Metabolism and Enzymes | 7.83 |
| Mendelian Genetics | 8.14 |
| Photosynthesis | 8.36 |
| Scientific Reasoning | 9.44 |
| Embryonic Development | 9.68 |
| Immunology | 9.71 |
| Viruses | 9.80 |
| Bioenergetics | 9.38 |
| Fundamentals of Chemistry | 10.40 |
| Evolution | 11.11 |
| Ecology | 12.00 |
| Plant Reproduction | 12.05 |
| History of Science | 13.15 |

**TABLE 4.**
Summary of average rankings for seventeen biology concepts listed from greatest to least importance as rated by major students.

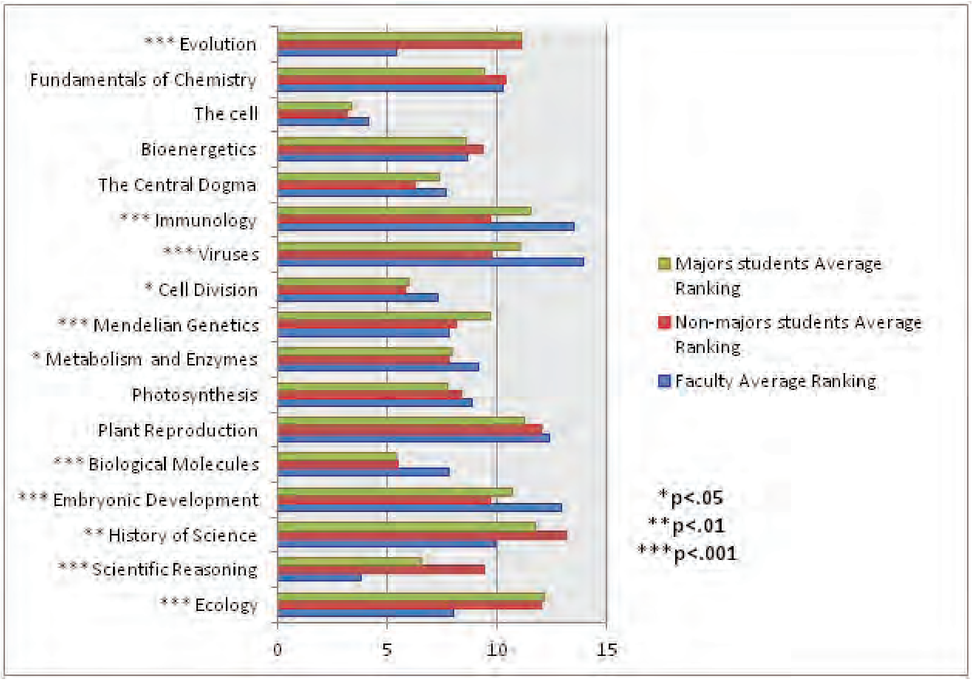
| Concept | Non-major Students Average Ranking |
|---|---|
| The Cell | 3.32 |
| Biological Molecules | 5.37 |
| Cell Division | 5.95 |
| Scientific Reasoning | 6.56 |
| The Central Dogma | 7.34 |
| Photosynthesis | 7.74 |
| Metabolism and Enzymes | 7.96 |
| Bioenergetics | 8.58 |
| Fundamentals of Chemistry | 9.43 |
| Mendelian Genetics | 9.70 |
| Embryonic Development | 10.68 |
| Viruses | 11.05 |
| Evolution | 11.14 |
| Plant Reproduction | 11.28 |
| Immunology | 11.51 |
| History of Science | 11.76 |
| Ecology | 12.17 |

non-majors, 5.95 majors), and Biological Molecules (5.5 non-majors, 5.37 majors). The bottom three were History of Science (13.15 non-majors, 11.76 majors), Ecology (12.0 non-majors, 12.17 majors), and Evolution (11.11 non-majors, 11.14 majors).

From the faculty, major, and non-major student treatments, there were eleven significant ($p \leq 0.05$) differences among the mean scores. The differences and their p values found were as follows: Evolution ($p=0.0001$), Immunology ($p=0.0001$), Viruses ($p=0.0001$), Cell Division ($p=0.014$), Mendelian Genetics ($p=0.0001$), Metabolism/Enzymes ($p=0.043$), Biological Molecules ($p=0.0001$), Embryonic Development ($p=0.0001$), History of Science ($p=0.002$), Scientific Reasoning ($p=0.0001$), and Ecology ($p=0.0001$). Table 1 summarizes the average ranking for all of the concepts and the p-values, indicating which were significant ($p \leq 0.05$). Tables 2, 3 and 4 provide a visual summary of how the three different groups (professors, non-majors, and majors) ranked the seventeen concepts in order of importance.

The LSD post hoc data indicate significant differences ($p \leq 0.05$) between faculty and science majors in all of the following eleven areas: Evolution, Immunology, Viruses, Mendelian Genetics, Metabolism and Enzymes,

**FIGURE 1.** Average rankings (1-17) for majors students (green), non-majors students (red), and faculty (blue) for the 17 biological concepts. The lower the number is, the more important the concept; conversely, the higher the number, the less important the concept was ranked.




Biological Molecules, Embryonic Development, History of Science, Scientific Reasoning/Method, Cell Division and Ecology. Comparisons between faculty and non-major biology students also had significant differences ($p \leq 0.05$) in all of the areas listed above with the exception of Mendelian Genetics and Metabolism and Enzymes.

There were also significant differences between average rankings from non-major and major students for the following concepts: Immunology, Viruses, Mendelian Genetics, History of Science, and Scientific Reasoning/Method (Table 5).

**TABLE 5.**
Significant differences in rankings between major and non-major biology students.

| Concept | P value |
|---|---|
| Immunology[1] | 0.0001 |
| Viruses[1] | 0.015 |
| Mendelian Genetics[1] | 0.003 |
| History of Science[2] | 0.047 |
| Scientific Reasoning/Method[2] | 0.0001 |

[1] Non-major students ranked these concepts as more important than major students did.
[2] Major students ranked these concepts as more important than non-major students did.

Faculty ranked Evolution and Ecology as two of the most important concepts to teach; students ranked them as two of the least important. This is perhaps the most surprising of all the data. Evolution is the capstone of all biology and thus, it was unexpected that students would place it near the bottom in terms of importance. However, others have suggested a similar concern (Alters and Nelson, 2002), and therefore teachers need to investigate methods to improve understanding of how evolution can best be integrated into biology courses. The National Research Council has recently shown (NRC, 2012) that approximately 40% of all the people in the US "believe" that evolution is false; and 32% of students with a college education think that evolution is not based on a solid scientific foundation. Indeed, 40% of high school biology teachers doubt the validity of the theory of evolution. Much of our students' thinking on this issue has been framed early in their education both in the home and in formal education. Thus, in a college classroom we often hear our freshmen students whisper, "Here it comes again."

Ecology is another great concern. Ecology helps students see the "big picture" instead of learning random facts, which often causes students to dislike science (Mason, 1992). In his book *The Diversity of Life*, Wilson

(1992) discusses the importance of ecology and describes biodiversity as priceless and an important part of humanity. Wilson (2006) argues there is a bond between humans and other species, and that we subconsciously seek these connections with the rest of life (Wilson, 1992). He has also suggested that students can integrate and make connections to all aspects of biology only if they are introduced to the "big picture" of biology, early in the course. He calls this "teaching from the top down." The survey results indicate that professors recognize the key role of ecology, but once again this study reveals that this key concept is not adequately understood and/or communicated to the students.

The discrepancy between faculty and student ratings on scientific reasoning/method is also interesting. Scientific reasoning skills are the foundation of experimental biology and science as a whole and are clearly needed for the citizen scientist (Burns, 2012); however, Tyser & Cerbin (1991) explained that teachers are often unsure how to teach thinking skills and how to incorporate this concept into their courses without sacrificing content. These data suggest that if the goal is to help create more scientifically literate citizens, a more concerted effort should be placed on using scientific reasoning as an active learning pedagogy.

There were significant differences in rankings between biology major and non-major students, but they were more consistent with each other than when the rankings were compared to faculty. The most significant difference among the students was scientific reasoning/method, with majors ranking this topic as more important than did the non-major students. STEM major students are often more exposed to scientific research and perhaps have more opportunity to see the importance of the scientific method and reasoning skills. Even though the course for majors is also an introductory course, students who have chosen biology as a major are more often already involved in some type of research or are taking other science courses simultaneously. Most non-major students will only take an introductory biology course at college in order to satisfy a general education requirement; therefore focus should be placed on skills like scientific reasoning, that will most improve the ability of a citizen scientist to reason and make rational scientific decisions that will impact communities for years to come. Given this scenario, perhaps our best and most creative teachers should be given the assignment of teaching our non-major students.

Another hypothesis that could explain the difference between majors and non-majors is how the biology course is taught for these two different student populations. Perhaps the majors-level course puts more emphasis on scientific reasoning because it will be a necessary skill for future major courses and lab work. However, as explained previously, it would be shortsighted to think that only those students majoring in science need to be scientifically literate and have the ability to reason and make scientific decisions.

Finally, the way in which textbooks are designed may also be contributing to the lack of theme integration (especially for ecology and evolution) as the students move from topic to topic. For example, Duncan et al. (2011) have shown that $<5\%$ of the figures used in textbooks (including those used in our study) stimulate creative thinking and scientific reasoning. These authors state that "… a lack of emphasis on the process of scientific investigation in the figures that appear in introductory college textbooks is an impediment to students' understanding of science."

## Conclusions

Faculty ranked the importance of eleven of the seventeen biology concepts in a significantly different order than the students. Evolution was ranked as one of the most important concepts for faculty, whereas students ranked it much lower. Ecology was ranked as least important by major students and third to lowest by non-major students, but was ranked much higher by faculty. Scientific reasoning/method was also ranked by faculty as one of the top three most important concepts to teach, while students ranked it significantly lower in importance. These results indicate that students are not learning or understanding the importance of what faculty view as the key concepts in biology. Evolution is the capstone of biology, and ecology is vital for understanding the "big picture" of biology. A clear understanding of these two concepts is a must for our citizen scientist. Scientific reasoning and the scientific method are the driving forces behind all experimental biology. More time needs to be devoted to the process of science so that an appreciation for scientific reasoning will sink in. The outcomes in this investigation may reflect previous student exposure to or experience with these biological concepts (in their homes, perhaps). This is probably why a large proportion of US citizens do not accept evolution as a vital capstone of all biology. We believe this study should be repeated on a larger scale, with faculty and student participants from throughout the nation, in order to evaluate the severity of the discrepancy between faculty and student perspectives of what is truly relevant in biology. The design of the illustrations in our textbooks clearly needs to be improved so that our students can see the value of scientific reasoning. This will undoubtedly help them see connections from theme to theme. It is hoped that all students leave their biology courses with the ability to apply biological principles in their lives, to help them recognize the importance of biology and to allow them the opportunity to solve real-world problems in their community, the nation, and the world.

## About the Authors

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*Gary M. Booth* is Professor of Plant and Wildlife Sciences at Brigham Young University. He received his B.S. and M.S. degree from Utah State University and a Ph.D from University of California, Riverside, all in entomology. Gary has taught Biology 100 as a Freshman Mentoring faculty for over 40 years. He was responsible for bringing service learning as an integral part of Biology 100 curriculum and is serving as a Leadership Fellow for a grant from the Keck Foundation in the development of the Nodal Program established through SENCER. He has been an active participant of SENCER for over 15 years.

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## Appendix A

***MASTERS RESEARCH SURVEY***

Dr. Gary Booth, Professor of Wildlife and Sciences at Brigham Young University, and his graduate student Jessica Rosenvall are performing a Masters thesis research project developed around seventeen biological concepts that should be taught in an introductory General Education biology class.

**Please fill out the following information:**

Your name (first and last) ____________________________________________

University where you work ____________________________________________

Your Department ___________________________________________________

Are you currently teaching? _______

If yes, which courses? _________________________________________________

If not, what do you do at the University? ___________________________________

Your age ________

**Please rank the following list by what you would consider to be the most important concepts to teach in an introductory non-major General Education biology class.**

**Rank the terms with:**

**1=** most important concept to teach through **17=** least important to teach.

*Write the numbers on the lines preceding these concepts.*

_____ Evolution

_____ Fundamentals of chemistry

_____ The cell

_____ Bioenergetics (cellular respiration)

_____ The Central Dogma

_____ Immunology

_____ Viruses

_____ Cell Division (mitosis and meiosis)

_____ Mendelian Genetics

_____ Metabolism and Enzymes

_____ Photosynthesis

_____ Plant Reproduction

_____ Biological molecules (carbohydrates, proteins, lipids, nucleic acids)

_____ Embryonic Development

_____ History of Science

_____ Scientific Reasoning/scientific method

_____ Ecology

____ Please put an X on this line if you give your consent to use your answers in our study.
We will not attach names to the study but will review the data as a whole.

*Thank you for your help. You can put this survey in Dr. Booth's box in the PWS office, sent it to his office (419 WIDB) or email it to us at gary_booth@byu.edu*