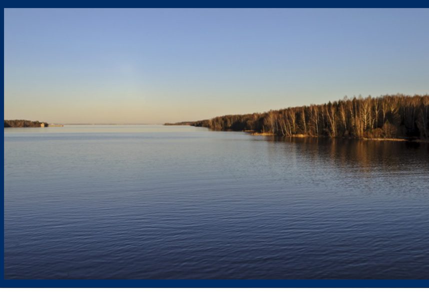

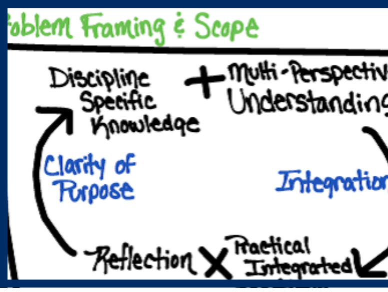

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Contents

From the Editors

In the Summer 2014 issue of *Science Education and Civic Engagement: An International Journal*, you will find four very different approaches to the impact, both locally and internationally, of science education on civic life. In a strong example of the scholarship of teaching and learning **Elizabeth Olcese, Gerald Kobylski, Charles Elliott** of the **U.S. Military Academy,** and **Joseph Shannon** of **South Seattle College** have documented their systematic and research-based approach to developing a valid assessment rubric for West Point's interdisciplinary Core Program. Their article "Meeting the Challenge of Interdisciplinary Assessment," notes that preparing students to address increasingly complex civic and societal challenges will demand a STEM-rich education that places greater emphasis on interdisciplinary courses and curricula. However, the problem of defining, and then measuring, "interdiscplinarity," has acted as a brake on the development of programs and courses that give students essential experience in integrating and synthesizing knowledge from multiple disciplines. The detailed report of their process, and the results of their first implementation, is a valuable contribution to a larger conversation, both about efforts to increase the civic impact of STEM learning, and the strategies used to assess those innovations.

Laura Romano, Denison University contributed an article detailing the integration of service learning and civic engagement activities into an undergraduate biology course. In "Discussing the Human Life Cycle with Senior Citizens as a Service-Learning Project in an Undergraduate Developmental Biology Course," the author describes how her students prepared posters explaining different stages of the human life cycle: gametogenesis, fertilization, embryonic development, fetal development, childhood (including adolescence), and adulthood (including senescence). Their posters were accompanied by activities designed to further engage the senior citizens who visited during a lab period at the end of the semester. While the senior citizens completed surveys, the students wrote short essays reflecting on the value of service-learning. The surveys demonstrated an increase in senior citizens' understanding of human development as well as current issues related to the discipline. The students' essays revealed that the project was beneficial in many ways, most notably, fostering a sense of civic responsibility among the next generation of scientists.

In "Science Bowl Academic Competitions and Perceived Benefits of Engaging Students Outside the Classroom," **Robert Kuech and Robert Sanford** of the **University of Southern Maine** offer a report on data they have collected on a well-established, but often overlooked and little studied, program of community-based informal science education, The National Science Bowl®. In the past 25 years over 240,000 high school and middle school students have voluntarily entered this highly competitive Department of Energy sponsored contest. To find out whether the time, discipline, and effort it takes to organize and participate in the Science Bowl is well invested, the authors surveyed the contestants in a Regional Science Bowl competition to ask what impact this program had on student learning and attitudes about science, as well as on other dispositions important to civic life, including leadership and teamwork. Their results strongly indicate that further research on the impact of The National Science Bowl competitions could yield valuable data on the impact of co-curricular and team-based efforts on students' engagement with science.

Robert Franco, Professor of **Pacific Anthropology** at **Kapi'olani Community College** in **Hawai'i** offers a summary of his experiences as an invited participant at two international conferences held in East and South Asia, both of which of which involved partnerships between U.S. Community Colleges and government educational initiatives in the respective countries. The first, an International Water Conference, was held at Sias University, Henan Province, China, which is a solely American owned university affiliated with both Zhenzou University and Fort Hays State University in Kansas. The conference brought together scholars and researchers from around the world to discuss the environmental and geopolitical implications of climate change, droughts, and sea level change on the region's future development, and the role that regional educational institutions and their students can play in addressing the problems. The second was a workingcoference of academic leaders seeking to establish a community college system in Mumbai, a joint project of Kapi'olani Community College, the University of Hawai'i, and the University of Mumbai. Franco's detailed report of these important international developments highlights the importance of the US community college model to other countries as they work to develop educational systems that are immediately responsive to the civic and economic needs of their regions.

— *Trace Jordan*
Eliza Reilly
Co-Editors-in-Chief

POINT OF VIEW

A Report on Community Colleges and Science and Civic Engagement in Asia:
A Yearlong and Continuing Journey

Robert W. Franco
University of Hawai'i

Throughout 2013 I had the opportunity to travel to East and South Asia, to explore connections between the work of community colleges and civically engaged science. What follows is a general summary of what was learned through a combination of ethnographic observation and ongoing scholarly engagement with Sias University in China, the Asia Pacific Higher Education Research Program (APHERP) at the East-West Center in Hawai'i, and the University of Mumbai in India. The report will conclude by suggesting how these international interactions relate to a new Teagle Foundation-funded project at Kapi'olani Community College and the Community College National Center for Community Engagement (CCNCCE).

International Water Conference at Sias University, Henan Province, China

Sias University is the first solely American-owned university in Central China, affiliated with both Zhengzhou University and Fort Hays State University, Kansas. It is located in Henan Province, which was the center of a rising Chinese civilization nearly 5,000 years ago. Today, more than 100 million people live in Henan, which is two-thirds the size of Arizona. Although the Yellow River does not flow through Henan Province as it once did, the river skirts the boundaries of the Sias campus.

Dr. Paul Elsner, who for 22 years served as Chancellor of the 10-campus Maricopa Community College System, invited me to make a presentation at the Sias University International Water Conference, May 22–25, 2013. Dr. Elsner knew that Kapi'olani Community College (KCC) and the University of Hawai'i at Manoa (UHM) had developed and sustained a strong service learning and civic engagement program called Malama i na Ahupua'a (to care for the ahupua'a), which engages students and faculty in restoring ancient Hawaiian watersheds throughout the island of O'ahu.

He knew about "Kapi'olani Sustainability and Service Learning" (KSSL, our new name), through our two-decades-long partnership with the CCNCCE, an organization that he founded and strongly supported as Chancellor. Dr. Elsner is currently on the Board of Sias University and saw striking similarities between water problems in Arizona and central China.

However, Dr. Elsner did not know of my earlier anthropological work in this field and its relevance to the conference topic. In 1995 I published a report for the UHM Water Resources Research Center (WRRC) entitled, "Water: Its Meaning and Management in Pre-contact Hawaii." This paper was developed in professional collaboration with Dr. Marion Kelly, who was an advocate for Native Hawaiian people and history and founded the UHM Ethnic Studies Department. Both the report and the collaboration coincided with the development of the Malama i na Ahupua'a program.

The WRCC report was set against the controversial theory linking irrigation with "oriental despotism" that Karl A. Wittfogel presented in in *Oriental Despotism: A Comparative Study of Total Power* (1957). Wittfogel analyzed the role of irrigation works, the bureaucratic structures needed to maintain them, and the impact that these had on society, coining the term "hydraulic empire." This theory has led many Western archaeologists to focus on early forms of irrigation and water management.

During the late prehistoric period in ancient Hawaii, irrigation and other water management practices supported the sociopolitical evolution of a proto-state. The report used archaeological data as a point of departure to analyze the meaning and management of water in this period. An analysis of Hawaiian chants, legends, and proverbs was woven into the archaeological data in an in an attempt to better understand the meaning of water to the indigenous people of the Hawaiian Islands.[1] The report concluded that intra-island (windward-leeward) and inter-island (geological-hydrological) variation produced important localized meanings of water, and that these meanings changed over time, largely in relation to population growth, production, intensification, and increasing sociopolitical complexity. My own research in this area provided a useful context for my participation in the international discussions that took place during my visits.

The Sias International Water Conference brought together international and Chinese scholars. Prominent international researchers included Dr. Jonathon Overpeck, who served as a coordinating lead author for the Nobel Prize-winning UN Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment (2007); Dr. Sharon Megdal, Director of the University of Arizona Water Resources Research Center; and Dr. Brian Fagan, with whom I studied archaeology at UC Santa Barbara in the early 1970s, and who is the celebrated author of *The Attacking Ocean* (2013), and other major world archaeology publications. Chinese researchers included: Dr. Zuo Qiting, Professor, College of Water Conservancy and Environmental Engineering, Zhengzhou University, and Director of the Water Science Research Center; Dr. Zhang Qiang, Deputy Director of Department of Water Resources and Environment, Sun Yat-Sen University; and Yao Tandong: Glaciologist at China's Institute of Tibetan Plateau Research.

China is one of the most water-rich countries in the world, but water resources are unevenly distributed and overwhelmingly concentrated in the south and far west on the Tibetan Plain, which also serves as a major water source for India. Water scarcity has always been a problem for Northern China and has been increasingly so as a result of rapid economic development. Major water engineering projects have been completed, and more are underway, to move water from the south to the north, with significant implications for Tibet-India-China relations. Major conference topics included severe water scarcity in Northern China, water quality and severe pollution in both Northern and Southern China, rural and urban challenges, and the likely deleterious future impacts of climate change, mega-droughts, and sea level.

The conference also served as a showcase for Sias University's innovative approaches to teaching and learning about water issues in China, such as a mesmerizing theatrical representation of water history in China, and their World Academy for the Future of Women (WAFW), which requires service projects as part of membership activities. Hundreds of students have gone through the Academy and created both short- and long-term projects of great value and impact. According to Dr. Linda Jacobsen, former Provost at Sias:

> Some young women shared that they applied to study at Sias *because* of the exciting service projects the WAFW members were sharing at home on semester breaks. Projects include the installation of drinking water filtration systems, environmentally safe agricultural practices, communal water area clean-ups, and eliminating violence against women. Over the years, these projects, which started locally in the university community, have expanded to regions within China where the members live.

1 I used similar data in deriving pre-contact Samoan perceptions of the meaning of "work" in my dissertation in 1985.

(Linda Jacobsen, Provost, Paper for 2014 Continuums of Service Conference, Honolulu)

My own presentation at the Water Conference was titled, "Service-Learning: Social Responsibility and Caring for Our Water Resources." The talk sidestepped the concept of "civic responsibility," partly because it was implied by the name of the host institution, the incipient "Institute for Social and Environmental Responsibility," but also because I was not sure whether the discourse on the "civic" was widely understood, or even acceptable in China. My presentation was the only one addressing sea-level rise and coastal water issues and it offered the GLISTEN project (Great Lakes Innovative Stewardship through Education Network) as a model for tackling major water issues in China. The paper was very well received (I'm sure the beautiful photos of Hawaiian ecosystems helped), and Dr. Jacobsen and I continue to dialog about future directions and partnerships.

East-West Center: Asia Pacific Higher Education Research Program (APHERP), Senior Seminar, at Hong Kong Institute for Education

In July 2013, I was invited to participate in a Senior Seminar entitled, "Research, Development and Innovation in Asian Pacific Higher Education," September 26–28, 2013. The seminar was led by APHERP Co-Directors, Drs. Deane Neubauer (UH Emeritus) and Dr. John Hawkins (UCLA), and brought together 14 higher education researchers, administrators, and faculty from China, Taiwan, South Korea, Malysia, Thailand, Australia, Chile, and the United States. My participation constituted a follow-up to East West Center-sponsored seminars in Honolulu and Indonesia that focused on developments in Asian-Pacific Education with a view toward 2020.

Dr. Neubauer's concept paper provided a focus for the seminar:

> Research and development (R&D) have long been a key component of what has generally been called "research universities." There is also recognition that in order to stay on the cutting edge of R&D, higher education institutions (HEIs) must increasingly strive for innovative R&D, and this has important implications for the structure and governance of higher education as well as numerous other factors of HE change and transformation. Furthermore, in a manner that may be unprecedented in the period of the so-called modern university, innovation, as almost a form of social responsibility, has been thrust upon the university. Interestingly and overwhelmingly, due to the role that the university is performing within the emergent knowledge society, innovation in the "knowledge transfer" functions of the university—the teaching role foremost among them—has become of increasingly greater importance.

I was invited to present a paper titled, "The University-Community Compact: Innovation in Community Engagement," which focused on the evolution of the American community college and its essential functions: university transfer, workforce development, and educating for engaged citizenship. The paper discussed the central differences among three related concepts:

- Civic engagement as the "participation of private actors in the public sphere, conducted through direct and indirect interactions of civil society organizations and citizens-at-large with government, multilateral institutions, and business establishments to influence decision making or pursue common goals" (World Bank).
- Civic responsibility as "the active participation in the public life of a community in an informed, committed, and constructive manner, with a focus on the common good" (Robinson and Gottlieb, American Association of Community Colleges).
- Community engagement as "the collaboration between institutions of higher education and their larger communities (local, regional/state, national, global) for the mutually beneficial exchange of knowledge and resources in a context of partnership and reciprocity" (Carnegie Foundation Community Engagement website).

Significantly, all three definitions skirt the discourse on democracy, which was advantageous in this context as I was uncertain about the advisability of discussing democracy in contemporary China. The presentation also used the GLISTEN initiative as a model and explored strategies for taking civic action on major water issues in East and Southeast Asia.

Community colleges are emergent in East, Southeast, and South Asia. However, five core features of American community colleges are underdeveloped. American community colleges are

1. Rooted in local communities, preparing local students for successful economic, social, and civic engagement in their regions;
2. "Open door" institutions, with less rigorous entry requirements;
3. Subsidized by states, with lower tuition rates;
4. Focused on rigorous workforce and career development through one-year certificates, two-year degrees, and lifelong learning;
5. Organized to prepare students to meet the requirements of rigorous baccalaureate programs.

In-depth interactions with the 14 seminar participants enabled deep and sustained discussions on these and other topics related to innovation in Asian-Pacific-American higher education. Most of the innovations discussed were not focused on the role of higher education in fostering civic engagement. They were instead focused on innovations in technology and on research and development as drivers of economic and workforce development. This was seen as higher education's larger social responsibility.

The seminar papers are currently being considered for publication by Palgrave-Macmillan, which will be publishing a new volume on *Service Learning in America's Community Colleges* later this year. Kapi'olani's contribution to that volume is entitled, "Service Learning's Role in Achieving Institutional Outcomes" (Yao Hill, Bob Franco, Tanya Renner, Krista Hiser, and Francisco Acoba).

Developing Community Colleges with the University of Mumbai

After the Hong Kong seminar, I traveled to the University of Mumbai for the fourth stage in discussions about establishing the University of Mumbai (UM) community colleges. These discussions have largely taken place at the level of senior leadership at KCC, UH, and UM, and had contributed to a grant proposal submitted to the Obama-Singh 21st Century Knowledge Initiative, advocating the building of higher-education bridges between India and the United States, the world's two largest democracies.

For three days in October, I participated in very full days of meetings. Major progress was made on the grant proposal, which focuses on the development of UM community colleges offering general education and training in Hospitality Management, Health Services, and Business.

India is determined to transform its future economic growth through higher education reform, seeking to expand access to quality workforce development programs as well as to improve employment prospects for India's burgeoning youth population of 700 million. The U.S. community college model is increasingly seen as one of the key vehicles driving this reform across India, bringing a formal two-year associate degree, job-focused certifications and industry linkages, and broader community and societal impacts, particularly in spurring income growth for diverse communities and populations.

On the evening of October 2, the UM leadership graciously escorted me to the University's glorious celebration of the birthday of Mohandas Gandhi. Earlier we had talked about Gandhi and Martin Luther King, and their roles in inspiring civil and civic action. We also discussed Martin Luther King's role in the American civil rights movement, and the concurrent development of America's community colleges throughout the 1960s. During the intensive three days we even developed a course outline focusing on the lives of these two men and Nelson Mandela, which would be used as part of the new general education curriculum to be implemented at the UM Community College at Ratnagiri.

Mumbai, with a population of 13 million, and Ratnagiri, with a population of 1.7 million, are located on India's long western coast on the Arabian Sea in Maharashtra State. This coastal ecosystem supports millions of residents and attracts millions of domestic and international visitors annually. We had in-depth discussions on how to promote sustainable tourism in Maharashtra State, particularly in the context of sea-level rise, and water challenges throughout India. Again, the SENCER GLISTEN model provided a pattern for collaborative and civic action.

Throughout the rest of October I developed the partnership proposal, which has four objectives:

- Develop a best practice University of Mumbai Community College at Ratnagiri (UMCCR) with an initial degree program in Hospitality Studies, followed by Health Studies and Business and Financial Services Programs.

- Develop at the University of Mumbai, Kalina Campus, The Center for Excellence in Community College Leadership, Teaching, Research, and Development (COE).
- Develop articulated degree pathways linking UMCCR, UM, and KCC and UH, initially in Hospitality Studies, and then in Health Studies and Business and Financial Services.
- Develop university-private-civil sector partnership agreements to support the UM-KCC-UH collaboration now and into the future.

Conclusion

Fresh water-saltwater convergences, and water availability and quality, are major global issues that affect the United States and East, Southeast, and South Asia. Higher education systems in all these areas are conducting research that informs public policy development. Meanwhile these problems are intensifying at an exponential pace. Our colleges and universities need to research, educate, and partner with non-profit organizations, and with local, state, and federal agencies to reduce the severity of the impact of water issues. The community colleges are well situated to do this work in close collaboration and authentic partnership with transfer universities that share the same ecosystems.

In January, 2014, KCC and CCNCCE received a three-year $270,000 grant from the Teagle Foundation titled "Student Learning for Civic Capacity: Stimulating Moral, Ethical, and Civic Engagement for Learning That Lasts." In this project seven community colleges in six states, New York (2), New Jersey, Louisiana, Arizona, California, and Hawai'i, are integrating the following "Big Question" into first- and second-year courses: "How do we build OUR commitment to civic and moral responsibility for diverse, equitable, healthy, and sustainable communities?"

This question is the kind of capacious, contested, and civic issue that SENCER continues to emphasize in its work on the STEM curriculum. I hope to present some answers to this question, from a community college perspective, at SSI 2015. Meanwhile, I welcome discussions on this question with university colleagues through the SENCER network as it expands to include countries around the globe.

About the Author

An ecological anthropologist, *Dr. Robert Franco* has published scholarly and policy research on the changing meaning of work, service, schooling, housing, and leadership for Samoans at home and abroad; health disparities confronting Samoan, Hawaiian, and Pacific Islander populations in the United States; the meaning and management of water in ancient Hawai'i; and sociocultural factors affecting fisheries in Samoa and the Northern Marianas. In 2009, he was lead editor in the publication of American Samoa's first written history.

At Kapi'olani Community College, University of Hawai'i, he has chaired the Faculty Senate and the Social Science Department, and led planning, grants, and accreditation efforts. As Director of Institutional Effectiveness, he bridges the cultures of faculty, staff, students, administration, and community partners to shape an innovative ecology of learning. With institutional commitment and support from federal and foundation sources, the college has emerged as a leader in service-learning for improved student engagement, learning and achievement. He has authored successful National Science Foundation (NSF) grants totaling more than $13 million since 2008. He is a Faculty Leadership Fellow for NSF's Science Education for New Civic Engagements and Responsibilities (SENCER) initiative, NSF's leading undergraduate science education reform program.

He is a senior consultant and trainer for national Campus Compact. He assisted in the development of the Carnegie Community Engagement Classification, and was named one of 20 national "Beacons of Vision, Hope, and Action" by the Community College National Center for Community Engagement.

He is newly the national program lead for the 3-year Teagle Foundation grant to develop OUR commitment to civic and moral responsibility for diverse, equitable, healthy, and sustainable communities.

Citations

Robinson, Gail and Gottlieb, Karla, A Practical Guide for Integrating Civic Responsibility Into the Curriculum, 2002:16, AACC Press, Washington, D.C.

RESEARCH PAPER

Meeting the Challenge of Interdisciplinary Assessment

Elizabeth Olcese
United States Military Academy

Gerald Kobylski
United States Military Academy

Joseph Shannon
South Seattle College

Charles Elliott
United States Military Academy

Introduction to Interdisciplinary Education

> "As the pace of scientific discovery and innovation accelerates, there is an urgent cultural need to reflect thoughtfully about these epic changes and challenges. The challenges of the twenty-first century require new interdisciplinary collaboration, which place questions of meanings and values on the agenda. We need to put questions about the universe and the universal back at the heart of university."
> – *William Grassie (2013)*

As the world becomes more complex, given the rapid expansion of technology, the changing nature of warfare, rising energy, and environmental crises, the value of an interdisciplinary education is increasingly obvious. Social, political, economic, and scientific issues are so thoroughly interconnected that they cannot be explored productively, either by experts or students, within clear-cut disciplinary boundaries.

Despite this fact, several problems arise when institutions try to incorporate interdisciplinary education into their programs. Boix Mansilla (2005) noted that the assessment of interdisciplinary work by students is of great concern. She explains that because faculty are often discipline-specific experts, they are unfamiliar with disciplines outside their realm of expertise and have difficulty defining interdisciplinary work. She goes on to explain that, as a consequence, "the issue [of standards] is marred by controversies over the purposes, methods, and most importantly, the content of proposed assessments" (2005, 16).

This paper offers one solution to this dilemma. The following analysis explores the current state of interdisciplinary education, both in academia broadly, and specifically, at West Point through its interdisciplinary Core Program. The sections that follow will highlight the current issues inherent in interdisciplinary education, define interdisciplinary education objectives, and finally, explain the adaptable, multi-functional, interdisciplinary rubric being implemented at the United States Military Academy

(USMA), a rubric designed to resolve many of the issues interdisciplinary educators encounter.

The Current State of Interdisciplinary Education in Academia

> "The demand is clear. Whether we try to take a stance on the stem cell research controversy, to interpret a work of art in a new medium, or to assess the reconstruction of Iraq, a deep understanding of contemporary life requires knowledge and thinking skills that transcend the traditional disciplines. Such understanding demands that we draw on multiple sources of expertise to capture multi-dimensional phenomena, to produce complex explanations, or to solve intricate problems. The educational corollary of this condition is that preparing young adults to be full participants in contemporary society demands that we foster their capacity to draw on multiple sources of knowledge to build deep understanding."
> – *Veronica Boix Mansilla (2005, 14)*

There are currently several studies, including evaluation measures, defining the essence of interdisciplinary education. The above quote from Boix Mansilla's "Assessing Student Work at Disciplinary Crossroads" highlights the challenge educators are experiencing in preparing students to meet today's most pressing problems. This paper will not attempt to address the structure of interdisciplinary education as an institutional convention, but only to define the essential skills and capacities that a student with interdisciplinary understanding would demonstrate. These definitions are essential to understanding and creating a framework for interdisciplinary learning, which is arguably the first step in adequately integrating it into educational programs. Interdisciplinarity is a difficult construct to quantify, and many educators have been unable to frame a definition of it or to assess it in student work. As a consequence of these and other challenges, only a limited number of colleges or universities have implemented formal interdisciplinary programs at the institutional level.

Several analyses (Boix Mansilla 2005; Boix Mansilla and Dawes Duraising 2007; Rhoten et al. 2008; Stowe and Eder 2002) address the key issues surrounding interdisciplinary learning in higher education and offer proposals on how to address them, starting with the definition of the term "interdisciplinary." One definition of interdisciplinary understanding is "the capacity to integrate knowledge and modes of thinking drawn from two or more disciplines to produce a cognitive advancement—for example, explaining a phenomenon, solving a problem, creating a product, or raising a new question—in ways that would have been unlikely through single disciplinary means" (Boix Mansilla 2005, 16; Boix Mansilla and Dawes Duraising 2007, 216). A definition is particularly important because "a clear articulation of what counts as quality interdisciplinary work, and how such quality might be measured, is needed if academic institutions are to foster in students deep understanding of complex problems and evaluate the impact of interdisciplinary education initiatives" (Boix Mansilla 2005, 16). An agreed-upon definition is currently lacking in academia, and this has resulted in inconsistent grading, teaching, and learning in interdisciplinary education.

One study of well regarded and established interdisciplinary programs in the U.S., which included Bioethics at the University of Pennsylvania, Interpretation Theory at Swarthmore College, Human Biology at Stanford University, and the NEXA Program at San Francisco State University, involved "69 interviews, 10 classroom observations, 40 samples of student work, and assorted program documentation" (Boix Mansilla and Dawes Duraising 2007, 4). The data were gathered in one-hour to 90-minute semi-structured interviews with faculty and students inquiring about the manner of assessment used in their respective programs. Next, examples of student work were used to give examples of what the institution viewed as meeting the definition of interdisciplinarity. From the interviews and student examples, the authors concluded that there are three core dimensions to student interdisciplinary work: disciplinary grounding, advancement through integration, and critical awareness (Boix Mansilla, 2005, Boix Mansilla and Dawes Duraising 2007). These core elements are represented graphically in Figure 1.

The first core element in Figure 1, disciplinary grounding, calls for strong base knowledge in individual disciplines. During the interviews, 75 percent of the interviewed faculty felt that strong subject-area knowledge was necessary for interdisciplinary education that did not sacrifice depth in exchange for breadth. However, the authors noted that the key to successful disciplinary grounding also included the thoughtful selection of which disciplines to use and how to use them.

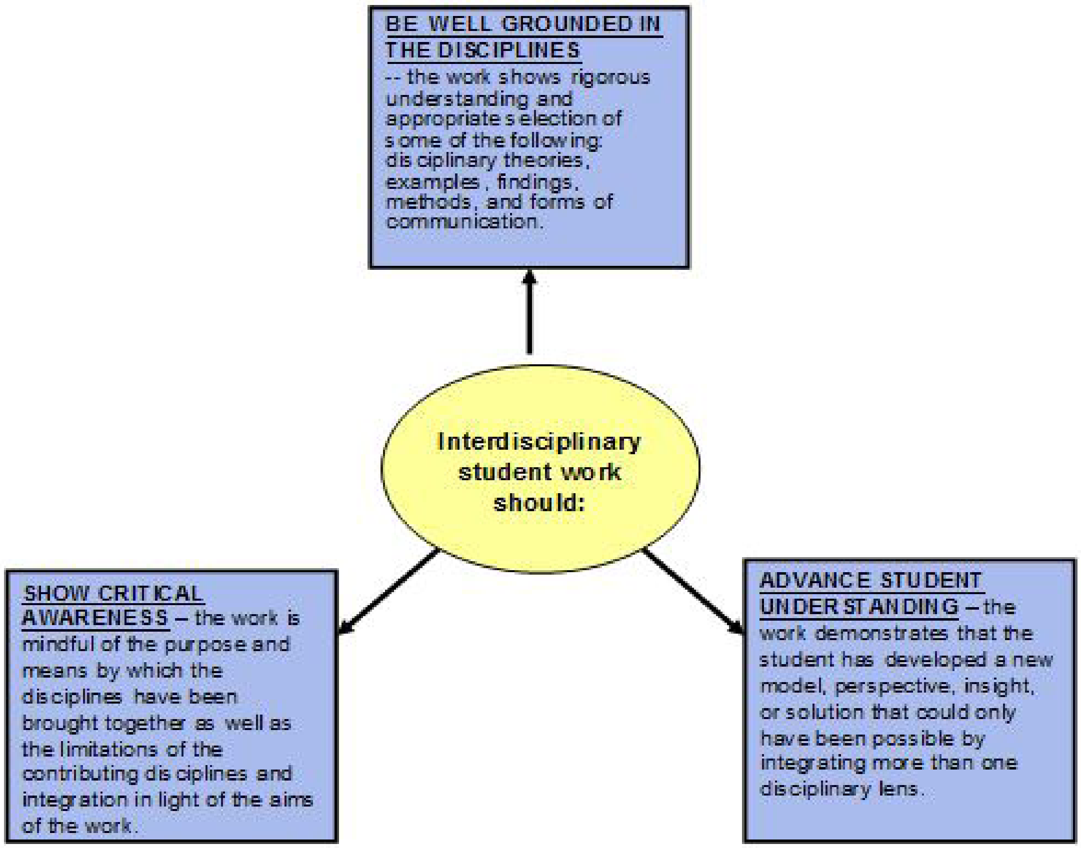


FIGURE 1. Three Interrelated Criteria for Assessing Students' Interdisciplinary Work (Boix Mansilla and Dawes Duraising 2007, 223)

Advancement through integration, the second principle, is universal in all student work in the sense that students are supposed to learn from the work they do; however, what sets it apart in interdisciplinary education is that "students advance their understanding by moving to a new conceptual model, explanation, insight, or solution" (Boix Mansilla and Dawes Duraising 2007, 225). In the study, sixty-eight percent of faculty identified advancement through integration as a necessary element in interdisciplinary understanding and as the quintessential element for the advancement of student understanding. However, various programs and their students interpret this core element differently. For example, some students in in the NEXA Program at San Francisco State University strive for *complex explanations*, which evaluate the extent to which disciplines are interwoven to create a broad picture of how interconnected different disciplines are on a given topic. Other students in the same program prefer to use *aesthetic reinterpretations* to connect the literary, historical, and social elements of a given topic. Other students, such as those in the Bioethics program at the University of Pennsylvania, choose to focus on the development of *practical solutions* based on of the use of multi-disciplined ideas. The final principle from Figure 1, *critical awareness*, refers to student work being able to withstand examination and criticism and explicitly calls for evidence of student reflection in their work. Student work needs to "exhibit clarity of purpose and offer evidence of reflective self-critique" (Boix-Mansilla and Dawes Duraising 2007, 228).

Rhoten et al. (2008) also conducted a study focused on the similarities and differences between the learning outcomes of liberal arts and interdisciplinary programs. For this particular study, the researchers used student and faculty surveys, interviews, and tests to gather data for their analysis. The authors explain that most liberal arts programs "must develop student capacities to integrate or synthesize disciplinary knowledge and modes of thinking," which is very similar to the type of synthesis that is expected from an interdisciplinary curriculum (Rhoten et al. 2008, 3–4). The main purpose behind this study was to

Liberal Arts Education	Interdisciplinary Education
Thinking critically, or possessing broad analytic skills	Tolerance of ambiguity or paradox
Learning how to learn	Sensitivity to ethical dimensions of issues
Thinking independently	*The ability to synthesize or integrate*
Empathizing, recognizing one's own assumptions, and seeing all sides of an issue	Enlarged perspectives or horizons
Exercising self control for the sake of broader loyalties	Creativity, original insights, unconventional thinking
Showing self assurance in leadership ability	Critical thinking
Demonstrating mature social and emotional judgment; personal integration	A balance between subjective and objective thinking
Holding equalitarian, liberal, pro science, and antiauthoritarian values and beliefs	An ability to demythologize experts
Participating in and enjoying cultural experience	Increased empowerment
(Winter et al., 1981)	*(Field et al. 1994 in Klein, 2002)*

TABLE 1. Comparison of Liberal Arts Education and Interdisciplinary Education Objectives (Rhoten et al. 2008)

identify the parallels between interdisciplinary and liberal arts programs, in order to show how a program can be made more interdisciplinary without changing its structure or content. Table 1 shows a summary of several parallels between a liberal arts education and an interdisciplinary education.

Rhoten et al. (2008) also analyzed empirical data to draw out trends on the "222 institutions considered 'Baccalaureate College-Liberal Arts institutions' under the 2000 Carnegie Classification system," whether the interdisciplinary programs offered were majors, minors, optional courses, or required courses (Rhoten et al. 2008, 5). In general, "interdisciplinary programs are still 'personally driven,' whereas departments are 'self-perpetuating'" (Rhoten et al. 2008, 6). "Personally driven" simply means that if students want to broaden their subject-area exposure they must do so on their own. "Self-perpetuating" refers to fact that departments within an institution need to act in their own self-interest in order to survive and thrive; therefore they tend to avoid interdisciplinary efforts. Interdisciplinary education does not support the mission of individual departments, and if students seek it, they must do so on their own initiative. One would therefore conclude that the only way to truly incorporate interdisciplinary education into schools is by making it institutionally mandated, at least for the core curriculum that all students are required to take.

Schools should strive to integrate interdisciplinary efforts into their institutions because "interdisciplinarity breeds innovation" (Rhoten et al. 2008, 12). Although such innovation carries tremendous benefits, the difficulty of measuring student and educator success was again identified as a barrier. Most schools that are already making efforts towards interdisciplinarity believe that they are somewhat successful according to Rhoten et al. (2008). However, in order to mark and measure success, and to continually improve interdisciplinary programs in schools, the authors propose a *value-added assessment*, which is intended to provide an "assessment regime that measures growth that has occurred as a result of participation in the institution or academic program" (Rhoten et al. 2008, 14). Moreover, some cross-cutting goals that are embedded especially in interdisciplinary studies, such as life-long learning, curiosity, creative thinking, synthesis, and integration, have acquired the reputation of being ineffable and, correspondingly, unassessable" (Rhoten et al. 2008, 83). This common problem was addressed by Stowe and Eder (2002) who identified several assessment measures that are placed on a continuum, as seen in Figure 2. These measures can also be used to better define interdisciplinary standards by providing a multi-tiered adjustable scale that can help to quantify the assessment of student work based on an instructor's desired outcomes.

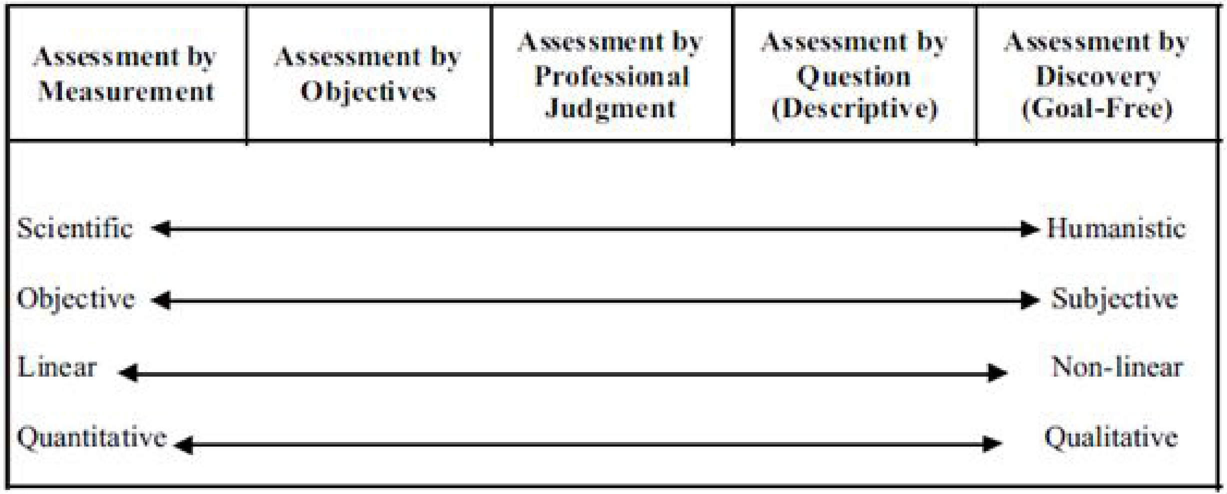


FIGURE 2. Perspectives on Assessment (Stowe and Eder 2002, 84)

Stowe and Eder (2002) state that using a rubric to define and measure interdisciplinary work would improve the "apparently subjective nature" of interdisciplinary assessment. They further recommend the rubric as a "visible standard—a scoring guide—that allows the assessor and the public, for that matter, to recognize expectations and make increasingly fine distinctions about the quantity and quality of student learning" (96). They expand on their recommendation by noting that assessment must be focused on both improving interdisciplinary learning and "improving student learning," and should be "embedded within larger systems… and create linkages and enhance coherence within and across the curriculum" (80). Without cooperation across different programs, it is impossible to foster an interdisciplinary learning environment.

An example of such cooperation can be seen at USMA, where several academic departments have moved towards a cooperative environment focused on interdisciplinary learning (Elliott et al. 2013). This paper will focus on the education of the USMA Class of 2016 from their freshman year, when the plan to use energy conservation and the NetZero [1] project was adopted to infuse interdisciplinary themes into their core courses. The five Student Learning Outcomes from this effort include four individual discipline-focused outcomes as well as a fifth, which aims to "develop an interdisciplinary perspective that supports knowledge transfer across disciplinary boundaries and supports innovative solutions to complex energy problems/projects" (Elliott et al. 2013, 33). In a larger sense, this objective illustrates that interdisciplinary education addresses the mission of USMA and the Army's focus on the "development of adaptive leaders who are comfortable operating in ambiguity and complexity will increasingly be our competitive advantage against future threats to our Nation," as outlined by General Martin Dempsey, Chairman of the U.S. Joint Chiefs of Staff (Elliiott et al. 2013, 30).

Framing the Problem

The Academy produces graduates who can think dynamically in the ever-changing world described in the quotes from Grassie and Boix Mansilla at the beginning of this article. At West Point, this is accomplished by taking not only a multidisciplinary approach to education, but also an interdisciplinary one. The Academy's Core Curriculum describes the required classes that all cadets must complete or validate. The Core Curriculum does not include any classes required for a cadet's major. Other non-academic requirements include three tactics courses and seven physical education courses. The interdisciplinary aspect is a new addition to the curriculum. In recent years, several committees have recommended promoting interdisciplinary approaches to better meet both the Academy's and the Army's goals as outlined in Elliott et al. (2013).

To achieve these goals, several academic departments involved in the Core Curriculum developed an interdisciplinary

1 NetZero is an energy initiative by the Department of the Army on several Army posts, including West Point, to produce as much energy as it consumes by the year 2020.

program for the entering plebe[2] class, the Class of 2016. During the first week of classes, freshmen wrote an essay in their Introduction to Mathematical Modeling course, or MA103, about how they would use concepts from different courses to tackle the challenges that NetZero and the alarming problem of energy consumption in the Army pose to West Point. After thirty instruction sessions (approximately thirteen weeks), the freshman revised these essays in their Composition course EN101. This time they used the knowledge acquired throughout the semester in the English course and in the other courses they were taking. Faculty from the Department of Mathematical Sciences and the Department of English and Philosophy evaluated these revised essays from different perspectives to emphasize the importance and relevance of multiple disciplines. This led to the realization that it was impossible to adequately compare the essays, since the assignments, rubrics, and faculty were not consistent and there was no common rubric to standardize the grading approach. To mitigate this challenge, the essays were compared in our study using the Flesch-Kincaid[3] test and a comparison of the final grades for the various essays. Scores for a sample of three essays for 25 students, a total of 75 essays, were used to compare improvement in a measureable, quantitative manner. The test consisted of a null hypothesis that there was no significant difference among the ratings, indicating neither improvement nor deterioration of scores from the different assignments throughout the semester, and an alternative hypothesis that there actually was a difference between scores. A two-tailed t-test yielded p-values ranging between 0.3 and 0.6. This indicated that the Flesch-Kincaid results were inconclusive, meaning that neither the null nor the alternative hypothesis could be rejected.

Despite the inconclusive results of the Flesch-Kincaid test, there was a demonstrated improvement in student work, albeit an improvement that was perceived on the basis of a subjective analysis of the essays. Therefore, a new rubric was developed to re-grade all of the essays in a standardized fashion against the desired elements for that particular set of assignments. To facilitate a comparison, this new and straightforward rubric aimed at grading each assignment from the different departments on the same scale. The grades were on a 1–10 scale, and the rubric can be seen in Table 2. The essays were then re-graded according to the same rubric and the results were compared again using a two-tailed t-test.

The challenge in evaluating interdisciplinary work is that the term "interdisciplinary" is not well-defined or broadly understood. This became even clearer after the Chemistry faculty conducted an interdisciplinary group capstone in the General Chemistry course with the Class of 2016 during the second semester of their freshman year. The capstone presented the students a complex and challenging energy problem that was both current and militarily relevant to their future roles as Army officers. This project required groups of students to write a memorandum summarizing their findings on an experimental, portable, and green battery recharger for soldiers in the field, and then to provide a presentation of their results to their commander. Cadets conducted an experiment on the battery recharger to test its efficiency, to compare it to current recharging methods, and to address the social and leadership challenges that would occur when this new equipment was integrated into a unit. In addition, the capstone leveraged the students' various courses and experiences to scaffold understanding of key concepts and technology necessary to engage the problem. The freshman cadets were expected to utilize what they learned from math modeling, information technology, general psychology, and general chemistry courses in formulating their solution.

The rubric used to grade these capstones was developed by the Chemistry faculty with input from all the participating courses, and then later utilized by the Chemistry faculty in assessing the capstones. The collaborative rubric identified numerous concepts in each course, and as a result, it was several pages long. Perhaps most significantly, it did not define the term "interdisciplinary" for the faculty and the students in the capstone, nor did it make clear the associated

2 "Plebe" is a term referring to the freshman class at West Point.

3 A Flesch-Kincaid readability test is a formula designed to evaluate the difficulty and complexity of technical writing. It consists of two readings: grade level and reading ease. The former uses the formula

$$0.39\left(\frac{\text{total words}}{\text{total sentences}}\right) + 11.8\left(\frac{\text{total syllables}}{\text{total words}}\right) - 15.59$$

to calculate a level of understanding score rated 0-100 that generally correlates with the U.S. grade standards of level of education (i.e. a score of 8.2 means that paper is at an 8th grade level). The latter produces a score of 0-infinity (as it does not have a theoretical upper bound) using the formula

$$206.835 - 1.015\left(\frac{\text{total words}}{\text{total sentences}}\right) - 84.6\left(\frac{\text{total syllables}}{\text{total words}}\right)$$

to indicate the difficulty level of reading a paper. For this reading, a lower score indicates a more difficult paper. The Department of Defense uses this test to regulate its documents and manuals; most are required to be between a 6th and 10th grade level rating.

Grading Rubric for Sample Essays	
Interdisciplinary	How well does the cadet incorporate different disciplines into his proposed solution? Quality work will include multiple disciplines mentioned as well as the display of their relevance to engery conservation and to each other.
Creative Solutions/Logical Solution	Cadet is able to demonstrate the scope of the Army's problem with energy and offers creative solutions (beyond turning off the lights in the barracks).
Dynamic Modeling/Understanding	Cadet is able to display a developed understanding of how the mathimatical modeling process is relevant to mapping energy consumption and creating a solution to the Army's energy issues. Clear understanding of the complexity of the problem.
Presentation	Essay is logically organized, free of spelling and gramatical errors. No use of first person. After reading the essay a followable message is conveyed with thought-out, logical, explained points. Essay has a clearly defined topic with good conclusion.

TABLE 2. Table 2. Rubric Used to Evaluate the Population Sample of NetZero Essays from Fall 2012.

expectations. At the conclusion of the rubric, faculty were asked to rate on a 1–10 scale how interdisciplinary their students' submissions were. The results, displayed in Figure 3, had a standard deviation of .186 and were inconsistent in both the average instructor rating and the range of different ratings faculty assigned. This indicated that the faculty did not share the same understanding of "interdisciplinary" in assessing student work.

Boix Mansilla and Dawes Duraising (2007) state that student interdisciplinary work should "be well-grounded in the disciplines" "show critical awareness," and "advance student understanding" (223). These criteria both define the basic learning objectives of an interdisciplinary education and address the need for baseline knowledge in the subjects being addressed in student work. While these criteria may not be included in a rubric or other grading mechanism, they provide more of a defined objective regarding interdisciplinary student work.

Although the idea of graduating interdisciplinary-minded students is appealing to many programs, the challenge of measuring the success of interdisciplinary curriculums in producing these "multi-disciplined" graduates has yet to be addressed. The problem of scaling and measuring interdisciplinary education is itself interdisciplinary in nature and, consequently, an abstract idea for many (Boix-Mansilla and Dawes Duraising 2007, 218). Interdisciplinary education evaluation currently lacks a "sound framework" for assessment

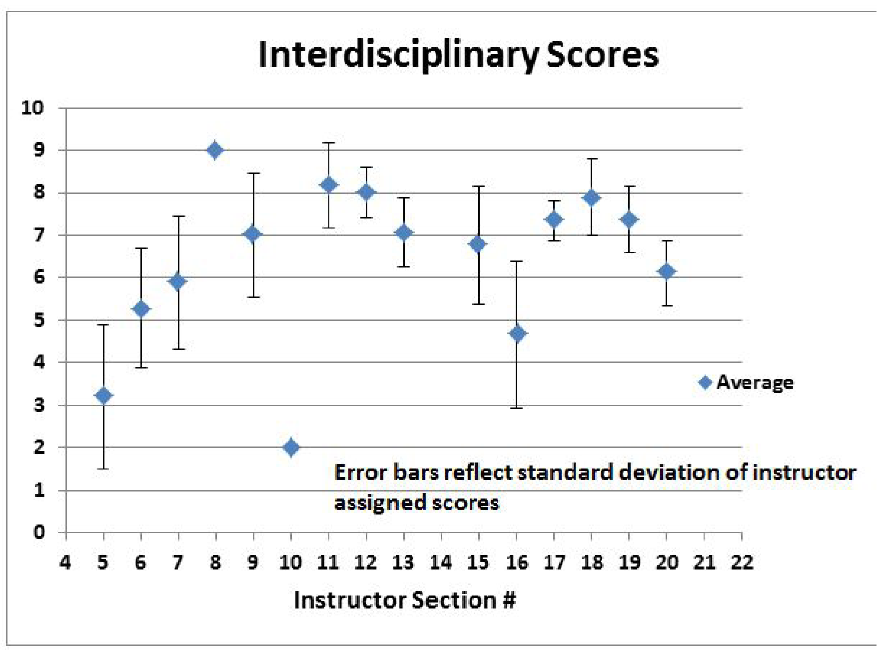


FIGURE 3. Chemistry Instructor Evaluation of Interdisciplinary Synergy in Capstone Projects during Spring 2013. *Courtesy of the United States Military Academy Department of Chemistry and Life Sciences.*

since the effects of interdisciplinary efforts on student learning are neither well-defined nor proven (Boix Mansilla 2005, 18). As seen in Figure 2 (Stowe and Eder 2002), the assessment of interdisciplinary work is a non-static scale where the balance between the perspectives and entities is never quite the same from project to project, or from class to class. Stowe and Eder (2002) offer a flexible scale for assessment that allows each interdisciplinary quality to be judged according to faculty expectations: how discovery-oriented versus objective-orientated do they want student assignments to be? Rhoten et al. (2008) do correlate several common learning outcomes of a liberal arts education with their interdisciplinary counterparts as seen in Table 1. Although useful for demonstrating extensive possible outcomes and correlations, the linkages are broadly defined and do not specify objectives; this exemplifies the issues of scale, definition, and the non-quantified nature of interdisciplinary education that currently prevail in academia.

All of the aforementioned problems can be traced to a lack of clarity on standards (Boix-Mansilla 2005, 16). Stowe (2002) explicitly calls for a standard for grading, collecting data, and creating a shared understanding, which he suggests could be found in a rubric. A standardized rubric, which is adaptable to several mediums and is general enough to be applicable to several disciplines, is desperately needed for evaluating and assessing interdisciplinary work. Such a rubric needs to clearly define the necessary elements of an interdisciplinary product and be sufficiently adaptable to align with project requirements; this would resolve several of the problems we have identified. In addition, Stowe and Eder (2002) call for the inclusion of very specific elements in a rubric, so that it can address current problems and properly evaluate interdisciplinary work. Among these requirements are assessing complex intellectual processes, promoting objectivity, reliability, and validity in assessment, clearly defining learning objectives for students, and being flexible and adjustable for course or curriculum progression (96). Although we conducted a thorough search, we failed to find a rubric that adequately fulfills this need.

Interdisciplinary Rubric Development

The goal of the rubric developed at USMA is to create a grading mechanism that can be used in multiple project mediums across multiple disciplines. Simultaneously this rubric maintains the integrity of the interdisciplinary goals by creating a more defined standard with which to grade interdisciplinary student work. The rubric also contains open areas for point allotment as well as weighting for each category, which allows faculty to allot points and focus where they see fit. Developing such a rubric required several steps: defining the term interdisciplinary, identifying the elements that student work needs to demonstrate in order to illustrate interdisciplinary thinking, creating a model that visually represents the interconnectivity of these elements, and then using the defined elements and model to arrive at the rubric categories.

The first step in the rubric development process was to define the term interdisciplinary:

> **Interdisciplinary:** *The seamless integration of multi-dimensional, multi-faceted ideas into a clearly demonstrated understanding of an issue's breadth and depth, with sound judgment and dynamic thinking.*

Boix Mansilla's definition of interdisciplinary understanding[4] provided the starting point for the development of the rubric. Additionally, material from the research discussed above identified missing elements from Boix Mansilla's definition. For example, the best students' interdisciplinary work included ideas from multiple disciplines that were integrated to demonstrate the level of understanding that the student has attained.

The second step in the rubric development process was to expand the definition of interdisciplinary, in order to create a shared understanding between students, faculty, and those evaluating the interdisciplinary work. To this end, the feedback and lessons learned from previous student work were used to identify the elements common to successful interdisciplinary work. These principles include: discipline specific knowledge, multi-perspective understanding, integration, practical integrated solutions, reflection, and clarity of purpose. To illustrate the interconnectivity of these principles, a conceptual model of the characteristics was created. Initially, the intention was to create a linear model to represent the core principles. However, several issues, such as missing connections and limited complexity, led to the immediate conclusion

4 Boix Mansilla defines interdisciplinary understanding as "the capacity to integrate knowledge and modes of thinking drawn from two or more disciplines to produce a cognitive advancement… in ways that would have been unlikely through single disciplinary means" (2005, 16).

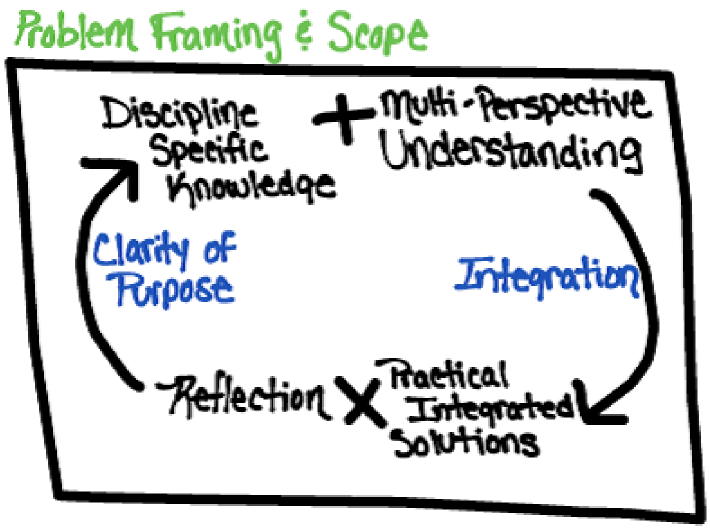


FIGURE 4. The Cyclical Model of the Key Interdisciplinary Characteristics. This model demonstrates the interconnectivity of the defined interdisciplinary elements.

that a linear model could not completely describe complex nonlinear problem solving. The resulting model, which illustrates a cyclical thinking process, is shown in Figure 4.

The model begins with the framing and scoping of the problem before the application of discipline-specific knowledge, which as we have seen is an essential starting point for interdisciplinary work. The core principle of the integration of ideas was partitioned into multi-perspective understanding, integration, and practical integrated solutions. Multi-perspective understanding and discipline-specific knowledge are connected by an addition sign, which symbolizes understanding a topic from multiple perspectives. This illustrates that students must be able to use discipline-specific knowledge to make this essential connection. The arrow labeled "integration" in the lower part of the model represents the synthesis of discipline-specific knowledge and multi-perspective understanding into practical integrated solutions. Practical integrated solutions are then connected to reflection via a multiplication sign to show that reflection has a multiplicative effect on interdisciplinary understanding. The arrow labeled "clarity of purpose" represents the cyclical process and shows the compilation of all the previous elements back into discipline-specific knowledge. The knowledge gained from the various parts of the cycle can be used in the further learning of other applicable disciplines. This model's goal is not to explain the rubric, but to illustrate how interdisciplinary education is cyclical in nature, how the characteristics of interdisciplinary understanding are relevant to interdisciplinary education, and how student learning should continue to build.

Next, the core principles of what makes student work interdisciplinary were established, defined, and examined. The elements in Figure 1 above, taken from Boix Mansilla and Dawes Duraising (2007), were used as a starting point for the development of this rubric's core principles: be well grounded in the disciplines, show critical awareness, and advance student leaning through understanding (223). For the purpose of this rubric, some elements were modified and expanded to create six core principles. A list of the six core principles that were incorporated into the rubric, along with their definitions, appear in Table 3.

Problem framing and scope are derived from the idea that interdisciplinary work should show critical awareness. The definition used in the rubric is very flexible, so that educators can adapt it for different project mediums and faculty, departments, and/or university requirements. Critical awareness, as defined by Boix Mansilla (2007), includes the

Core Principle	Definition
Framing and Scope	Cadets are able to clearly define a stated purpose/thesis with the appropriate knowledge.
Discipline Knowledge	Strong demonstrated subject knowledge applied correctly.
Integration of Ideas	Multi-dimensional feasible, practical solution with multi-faceted and seamlessly connected ideas.
Clarity of Purpose	Demonstrated clear understanding of the topic's breadth and depth with a defined purpose of investigation.
Reflection	Connection of ideas indicating reflection of the interconnectivity of disciplines and importance of the issue at large.
Appropriate Presentation	Information is presented in the appropriate medium with proper tone, word choice, spelling, grammar, etc.

TABLE 3. Basic Definitions of Mastery in Each of the Six Core Principles of the Interdisciplinary Rubric

definition of purpose as well as the integration of ideas. The definition used for problem framing and scope in the rubric requires that the student's work have a clearly defined purpose. This was created as a separate category because we had observed a clear trend of misunderstanding among faculty regarding the level of complexity that they expected. This is an important aspect of student interdisciplinary understanding; it allows the faculty to scale assignments according to the expected level of student understanding and allows the student to recognize just how complex and multi-disciplined a product the instructor is seeking. For example, if students were assigned a project on how to effectively stock a warehouse, an instructor would not have the same expectations of a freshman who has taken only introductory courses in mathematical modeling and economics as of a senior who had taken nonlinear optimization, supply chain management, and microeconomics courses. Having this requirement in the rubric makes clear the expectation that students will properly identify what they want to address, and also allows the instructor to have a frame of reference in a project.

The rubric's second core principle, *discipline knowledge* is well grounded in the disciplines and is intentionally more open-ended, so that it can be readily adapted to different departments, projects, and situations (Boix Mansilla 2007). Identifying theories, examples, findings, methods, etc. may not be relevant or necessary in a given problem. Therefore, although the evaluator is given an area in the rubric that calls for disciplinary knowledge, the rubric does not explicitly indicate how that knowledge is to be graded. For example, in our warehouse stocking project, a freshman might be expected to mathematically model the effects of changing employee wages on productivity. A university senior, on the other hand, might be expected to produce a business recommendation to stakeholders by addressing the intricacies of supply chain management on warehouse profits as well as its psychological implications for employees. The discipline knowledge area of the rubric enables the evaluator to determine how much knowledge and understanding students are expected to demonstrate, while ensuring that the importance of disciplinary understanding is not lost on an interdisciplinary project.

The *integration of ideas* principle is really the quintessential element for the interdisciplinarity of this rubric. All six core principles are important interdisciplinary factors, but if this element were removed, the rubric could be used for a project that is not interdisciplinary. Integration of ideas derives its meaning from the critical awareness and advanced student understanding pieces identified above in Figure 1. This rubric defines integration of ideas as multi-dimensional, feasible, practical solutions with multi-faceted and seamlessly connected ideas. It is important to note the difference between being integrated and being seamlessly integrated. The seamless integration of ideas, which can take on different meanings depending on the assignment, is an indicator of true multi-dimensional, multi-faceted understanding. Seamless integration. We define the term seamlessly integrated to mean that ideas are not simply laundry-listed, but instead are connected in an intelligent and logical fashion. The definitional elements of multi-dimensional and multi-faceted identify the need for complexity in student work. It is multi-dimensional when students make use of multiple dimensions of their education or, in other words, use multiple disciplines, in their work. Multi-faceted means that students are able to use evidence and knowledge to back up their multi-dimensional claims. The most important component is that students be able to demonstrate a clear understanding of what they are presenting. This also relates to a student's ability to demonstrate the span of an issue's breadth and depth. In other words, students should be able to apply disciplines to an issue or topic with an appropriate understanding of the level of each of the disciplines. The use of extraneous disciplines merely for the sake of incorporating more disciplines does not necessarily make student work interdisciplinary. In fact, it contradicts the idea of advancing the complexity of the student's thought process.. Students who apply the appropriate level of discipline breadth and depth indicate their ability to use sound judgment or logic, as well as their ability to think dynamically.

The next two core principles, *clarity of purpose* and *reflection*, were added to address the students' failure to internalize what they were learning and understanding; this was revealed during the analysis of the USMA interdisciplinary program. The main challenge was that students did not fully grasp why a given project was interdisciplinary, or why that was important. To alleviate this, the core principle clarity of purpose was added to the rubric to help students understand the "why"; the intent was to motivate them to define the purpose of their investigation and to take an in-depth approach to the problem. This is different from problem framing and scope in a very important way: problem framing and scope focuses on a well-defined thesis statement or purpose statement, whereas clarity of purpose focuses on the content of student work. In other words, problem framing and scope ask whether students have a clearly stated framework for their project, while clarity of purpose asks whether they demonstrate their personal interdisciplinary understanding and then explain it well to their audience. Similarly, the next principle, reflection, calls for a clear and delineated connection of ideas and an indication that students have reflected on the interconnectivity and importance of their areas of study. These two core principles are drivers of internalization and cognitive advancement in interdisciplinary learning. They are particularly important because often students do not reflect on what they have learned. The reflection piece is intended to facilitate a deeper understanding of what they are learning and to encourage students to consider how the material fits into the greater scheme of their education.

The final element of the rubric shown in Table 3 is the *presentation principle*. This principle calls for information that is presented in a suitable medium with proper tone, word choice, spelling, grammar, etc. In short, did the students address the audience correctly and present their knowledge intelligently while doing so? This section can be adapted to the type of project and course for which the rubric is being used. For example, English faculty would probably expand this section because of its importance to their learning outcomes, whereas chemistry faculty may place more emphasis on the discipline-knowledge portion.

The newly developed rubric was presented to the Math course leaders for use on the freshman's "mini" [5] capstone exercise in December 2013. The rubric was sent to the faculty with minimal guidance. The feedback from the course director made it clear that the students and faculty did not fully grasp the intention or expectations behind the rubric. A few factors contributed to this: sixty-six percent of the faculty were new to the department; the interdisciplinary expectations were not fully explained to the faculty; although everyone received the rubric, each instructor created his or her own rubric for the mini-capstone; and the students who took the mini-capstone and the faculty who graded their work were under significant time pressure. The mini-capstone in its creation, execution, and grading was not given adequate time due to end of semester requirements at USMA during the November-December time period. An important conclusion from this feedback was that the faculty needed to have a common understanding of what is expected on an interdisciplinary project. To achieve this for the General Chemistry capstone project in the spring of 2014, a grading calibration exercise was conducted. This calibration included good and poor examples of interdisciplinary work from the previous year's chemistry capstone, and showed faculty how to distinguish between good and poor work and how to use the rubric in assigning a grade.

Implementing the Interdisciplinary Rubric

The first step in implementing the rubric was calibration with the faculty. With such an exercise, the faculty should take away a common understanding of what exactly interdisciplinarity is as well as the knowledge of what constitutes a good final project. The plan for the calibration exercise developed for USMA faculty who would be grading the CH102 General Chemistry capstone in the spring of 2014 was an hour-long presentation and discussion. Prior to the presentation, faculty received a packet of examples of cadet work in each of the major portions of the previous year's capstone project. The examples included "A" work as well as examples of common integration errors students make: the "laundry list," the "tacked on at the end," and the "no real knowledge" integration errors. The "laundry list" is an example of how a student may mention and be knowledgeable in multiple disciplines but does not integrate them, providing instead a "laundry list" of the different disciplines and explaining the relevance of each individually. The "tacked on at the end" error (or whatever we may call it) exemplifies how a student may go in-depth in one discipline, particularly in the discipline for which the assignment was given, then tack on a sentence or two at the end mentioning other disciplines in order to call the project interdisciplinary. The "no real knowledge" example presents a plethora of

5 The term "mini" is used to differentiate this capstone from the larger and more encompassing Chemistry capstone encountered by the cadets at the conclusion of freshman year.

ideas but does not demonstrate that the student learned or integrated disciplines and/or ideas. With these examples, faculty became more familiar with what correct and incorrect work looked like. The "A" level example was not meant to illustrate the perfect or only solution; it was merely one example. Faculty evaluated each example using the standard A, B, C, D, F grading scale based on how interdisciplinary they felt each project was.

At the start of the presentation portion of the rubric calibration, faculty were introduced to the interdisciplinary characteristics and model from Figure 4. This ensured understanding of interdisciplinary characteristics prior to the introduction to the rubric itself. After the characteristics were covered, the results from the exercise, which the faculty just had completed, were discussed. This clarified any misunderstandings that faculty had about the interdisciplinary characteristics, while the examples of chemistry capstones from the previous year provided a frame of reference. Next the rubric was thoroughly explained, showing how it was scalable, expandable, and concise to meet instructor needs for interdisciplinary student projects.

The General Chemistry capstone rubric for 2014 differs from its 2013 predecessor in two very important ways. First, it is significantly shorter; its two pages (compared to seven pages) emphasize quality over quantity. Instead of listing every detail of the project, the new capstone rubric has five categories that address the math modeling, leadership, information security, oral communication, and the required submission components of the project, all without specific details. This allows the students to be more creative in their answers to the given problem.

The 2013 rubric was not based on any interdisciplinary principles or examples. Instead, it listed specific requirements from the disciplines the students were supposed to integrate. The result was quite the opposite: the 2013 capstone projects tended to be disjointed because of the slew of specific requirements. This year's capstone rubric incorporates the interdisciplinary principles described in Table 3. *Problem framing and scope* is addressed in the Project Summary section with the requirement for a bottom line up front (BLUF), or thesis. *Discipline knowledge* is asked for in the Discrete Dynamic Modeling, Persuasion and Conformity in a Leadership Environment, and Information Security sections. Although the course-specific requirements must be addressed, *Integration of ideas* is assessed in the Oral Communication and Project Summary sections, which requires that fluid transitions and logically ordered and related ideas be integrated. *Appropriate presentation* is also adequately addressed in these sections, as the rubric lays out clear expectations of the written and oral presentations for students, including their tone, body language, and level of professionalism. *Clarity of purpose* and *reflection* are asked for in the Project Summary section, which calls for contingency plans and thoroughly explained analysis of the total problem.

Initial instructor feedback on the use of this rubric is that it better defined expectations for the students' interdisciplinary work, for both the instructor and the students. After using the rubric in the calibration exercise, instructors stated that they felt more confident and prepared than they had in 2013 when there was no such exercise and assessment tool available; this year they understood what was asked of them and of the students. Initial comparisons of the interdisciplinary assessments of the students' work from 2013 and 2014 are quite positive. On a scale of 0–10, the average interdisciplinary score given by instructors was 5.69 in 2013, with zero being the least interdisciplinary and 10 the most. (See Figure 3 for these data.) In 2014 this improved to 7.79 (actually 15.5/20). There was also less variability between instructors. For example, in 2013 the standard deviation of the mean scores assigned by each of the instructors was 1.86 (Figure 3). In 2014, the standard deviation between the instructors' mean scores was .98 (1.96/20), a decrease of over 47%.

Future Work and Conclusion

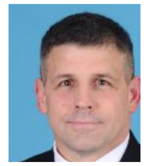
Now that the General Chemistry capstone for USMA Class of 2017 has concluded, several analyses must be completed to evaluate the progress of interdisciplinary education at USMA. At a minimum, an analysis of the grades and feedback from the students and faculty needs to be conducted. The analysis of the grades should include a distribution of grades compared with their expected distribution, as well as a quantitative and a qualitative analysis of the capstones compared to the previous years' capstones. This could be done using the methods previously employed, including the use of Flesch-Kincaid, paired t-test, the distribution of the faculty's interdisciplinary rating similar to Figure 3, and/or a cross-course sample of projects re-graded by the course director.

The discussion and research that have taken place at West Point since the first General Chemistry capstone project in 2013 indicate that the results of this year's changes should be positive. Although there is as yet no statistical evidence to demonstrate improvement, the general understanding of how interdisciplinarity looks, how to produce it, and how to assess it is much more expansive now than in 2013. The reason for this might be that faculty and students at USMA are now experienced with interdisciplinary work and have a clearer understanding of interdisciplinary assessment and its importance over the course of a year.

The world is a complex and rapidly changing place that requires its future scientists, scholars, engineers, teachers, and leaders to think dynamically and across disciplines.. Interdisciplinary assessment is necessary for the future of education, particularly at West Point where we recognize that "adaptive leaders who are comfortable operating in ambiguity and complexity will increasingly be our competitive advantage against future threats to our Nation" (Elliott et al. 2013, 30). Only time will tell whether this interdisciplinary rubric has met its goal of creating a grading mechanism that can be used in multiple project mediums across multiple disciplines. Given the extensive research and analysis done at West Point to create this much- needed and useful tool, the prospects for future interdisciplinary education are promising.

About the Authors

Elizabeth Olcese graduated with a Bachelor of Science degree in Operations Research from the United States Military Academy at West Point, NY in 2014. She served as a student researcher for West Point's Core Interdisciplinary Team focused on enhancing opportunities for interdisciplinary learning in West Point's core academic curriculum. Upon completion of the Quartermaster Basic Officer Leader Course at the Army Logistics School in Fort Lee, VA, she will serve as a second lieutenant for the 25th Infantry Division at Schofield, Hawaii.



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Lieutenant Colonel Charles (Chip) Elliott graduated with a doctorate in Geography and Environmental Engineering from Johns Hopkins University in Baltimore, MD and is a registered professional engineer in Virginia. He is currently the General Chemistry Program Director and the Plebe (Freshman) Director for the Core Interdisciplinary Team at the United States Military Academy. He has previously taught CH101/102 General Chemistry, EV394 Hydrogeology, EV488 Solid & Hazardous Waste Treatment and Remediation, EV401 Physical & Chemical Treatment, and EV203 Physical Geography. He is currently an Assistant Professor in the Department of Chemistry and Life Science.

References

Boix Mansilla, V. Interdisciplinary Understanding: What Counts as Quality Work?" Interdisciplinary Studies Project, Harvard Graduate School of Education.

Boix Mansilla, V. 2005. "Assessing Student Work at Disciplinary Crossroads." Change 37 (1): 14–21.

Boix Mansilla, V., and E. Dawes Duraising. 2007. "Targeted Assessment of Students' Interdisciplinary Work: An Empirically Grounded Framework Proposed. The Journal of Higher Education 78 (2): 216–237.

Elliott, C., G. Kobylski, P. Molin, C.D. Morrow, D.M. Ryan, S.K. Schwartz, J.C. Shannon, and C. Weld. 2013. "Putting the Backbone into Interdisciplinary Learning: An Initial Report." Manuscript submitted for publication, United States Military Academy, West Point, NY.

Grassie, W. (n.d.). "Interdisciplinary Quotes." Thinkexist.com. http://thinkexist.com/quotation/as-the-pace-of-scientific-discovery-and/1457907.html (accessed November 16, 2013).

Ivanitskaya, L., D. Clark, G. Montgomery, and R. Primeau. 2002. "Interdisciplinary Learning: Process and Outcomes." Innovative Higher Education, 27 (2): 95–111.

Newell, W.H. 2006. "Interdisciplinary Integration by Undergraduates." Issues in Integrative Studies 24: 89–111.

Repko, A.F. 2007. "Interdisciplinary Curriculum Design." Academic Exchange Quarterly 11 (1): 130–137.

Repko, A.F. 2008. "Assessing Interdisciplinary Learning Outcomes. Academic Exchange Quarterly 12 (3): 171–178.

Rhoten, D., V. Boix Mansilla, M. Chun, and J. Thompson Klein. 2008. "Interdisciplinary Education at Liberal Arts Institutions." Teagle Foundation White Paper.

Stowe, D.E., and D.J. Eder. 2002. "Interdisciplinary Program Assessment." Issues in Integrative Studies 20: 77–101.

Enclosure 1.

Category	Basic-F (__Points)	Novice-C (__Points)	Ingenious-B (__Points)	Mastery-A (__Points)
1. Problem Framing & Scope Weight ___%	1.1 Project purpose/thesis is not present or extremely unclear to the point where the audience does not understand the problem.	1.1 Project has a purpose/thesis that is missing information or contains too much information. The audience has a general understanding of the issue at hand but does not clearly understand.	1.1 Project has a well-stated purpose/thesis which enables audience to have a good understanding of issue at hand but is missing minor essential elements or contains extraneous information.	1.1 Project has a clearly stated purpose or thesis which enables the audience to clearly understand the issue at hand.
	1.2 Disciplines used do not apply directly to issue at hand.	1.2 Discipline use is faulty and contains 3+ extraneous subject use.	1.2 Appropriate disciplines/subjects used. 1-2 extraneous topics that do not tie into presentation well.	1.2 Appropriate disciplines/subjects used; no extraneous topics used.
	1.3 Ideas and issues very unclear.	1.3 ideas and issues unclear.	1.3 Ideas and issues delineated well.	1.3 Ideas and issues clearly delineated
2. Discipline Knowledge Weight ___%	2.1 Faulty base knowledge. Basic understanding in chosen topics is not present.	2.1 Baseline subject knowledge and understanding in chosen topics.	2.1 Good base subject knowledge and demonstrated basic understanding in chosen topics.	2.1 Strong base subject knowledge. Demonstrated depth of understanding in chosen topics.
	2.2 Inappropriate use of knowledge. Severe errors in application of discipline knowledge.	2.2 Appropriate use of knowledge. Severe errors in application of discipline knowledge to issue at hand.	2.2 Appropriate use of knowledge. Slight errors in discipline application to issue at hand.	2.2 Appropriate use of knowledge. Correctly utilizes discipline knowledge in application to issue at hand.
3. Integration of Ideas Weight ___%	3.1 Provides multi-dimensional solutions that are not feasible and/or practical due to little understanding of the issue at land. Connection of ideas is faulty.	3.1 Provides multi-dimensional, practical conclusions. Ideas may not be completely feasible because of errors or misunderstanding of the issue at hand. Ideas are connected, but not seamlessly.	3.1 Provides multi-dimensional, feasible, practical conclusions. Ideas are connected, but not seamlessly.	3.1 Provides multi-dimensional, feasible, practical conclusions with multi-faceted and seamlessly connected ideas.
	3.2 Integration not present or is irrational and/or ineffective. Imbalance of discipline detracts from intention of project.	3.2 Integration is present but is irrational or ineffectiveness. Disciplines are integrated but very unbalanced.	3.2 Integration is rationale and for the most part effective. Disciplines are integrated but are imbalanced.	3.2 Integration is rationale and effective. Disciplines are both integrated and balanced.
	3.3 Unclear or non-present findings, conclusions, recommendations, and/or examples. Or said topics not grounded in discipline(s') knowledge.	3.3 Decent findings, conclusions, recommendations, and/or examples with connections to discipline knowledge.	3.3 Sound findings, conclusions, recommendations, and/or examples grounded in discipline knowledge.	3.3 Quality findings, conclusions, recommendations, and examples from grounded discipline knowledge.
	3.4 Ideas are laundry-listed and are not well explained and/or integrated.	3.4 Basic range of subject integration present. Ideas somewhat laundry-listed and do not contain explanations or integration.	3.4 Good range of subject integration opportunities are exploited.	3.4 Full range of subject integration opportunities have been sought out and exploited.
4. Clarity of Purpose Weight ___%	4.1 Does not grasp the breadth and depth of the issue in question to an acceptable level.	4.1 Understands the scale of the issue in question but does not effectively communicate it.	4.1 Demonstrates a general understanding of the issue in question's breadth or depth.	4.1 Demonstrates clear understanding of the issue in question's breadth and depth.
	4.2 A general purpose of investigation is present but not to a satisfactory level or is not present.	4.2 Defines the purpose of investigation to a satisfactory level, but contains extraneous matter or loose ends.	4.2 Defined purpose of investigation is present.	4.2 Clearly defines the purpose of investigation.
5. Reflection Weight ___%	5.1 Ideas in project are connected and demonstrate minimal reflection on the importance of the issue at large.	5.1 Connections of ideas demonstrates some reflection on disciplinary interconnectivity and the importance of the issue at large.	5.1 Connection of ideas indicates student has reflected on the interconnectivity and importance of the issue at large.	5.1 Clear and delineated connection of ideas indicates student has reflected on the interconnectivity and importance of the issue at large.
	5.2 Course Specific Reflection (if desired)	5.2 Course Specific Reflection (if desired)	5.2 Course Specific Reflection (if desired)	5.2 Course Specific Reflection (if desired)
6. Appropriate Presentation Weight ___%	6.1 Information is conveyed in such a way that detracts from the understanding of the problem at hand.	6.1 Information is conveyed in such a way that the audience has a general understanding of the problem at hand. Instances of laundry-listing are present and slightly detract from the coherence of the project.	6.1 Information is conveyed in such a way that the audience understands the scope of the problem and ideas are well-conveyed. Minor instances of laundry listing that do not detract from the coherency of the project.	6.1 Information conveyed in such a way that audience understands the scope of the problem coherently conveye ideas (not laundry listed subjects).
	6.2 Presentation order is illogical and/or has discrepancies that detract from the logic, articulation, fluidity, or the presentation of ideas. Appropriate tone and/or dept not present.	6.2 Presentation order has discrepancies in logic or fluidity. Ideas are not well articulated. Appropriate tone and depth present, but is not overall effective.	6.2 Presentation order is logical and fluid with minor discrepancies. Ideas are articulated and conveyed well. Effective tone and depth present.	6.2 Presentation order is logical and fluid. Ideas are articulated and conveyed effectively. Appropriate and effective tone and depth present.
	6.3 Terms not defined appropriately or project presented with terminology in such a way that it detracts from the audience's understanding. And/or use of inappropriate terminology or language.	6.3 Appropriate terms used but not defined fully for audience/setting context.	6.3 Terms appropriately defined and used as needed for audience/setting; minor discrepancies in use or understanding of terminology or language.	6.3 Terms appropriately define and used as needed for audience/setting; appropriate use of terminology and language.
	6.4 Errors in grammar, punctuation, spelling, and format distract from the project content. Project format is generally incorrect.	6.4 Grammar, punctuation, spelling, and format contain significant errors that detract from the project content slightly. Project format is still generally correct.	6.4 Proper grammar, punctuation, spelling, and format used throughout with minimal errors. Project format uses general correctness.	6.4 Proper grammar, punctuation, spelling, and format use throughout with no errors.

TEACHING AND LEARNING

Discussing the Human Life Cycle with Senior Citizens in an Undergraduate Developmental Biology Course

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Denison University

Abstract
A civic engagement project was designed for undergraduate students in a developmental biology course to promote their understanding of the material as well as its relevance to issues in the local community. For this project, students prepared posters that focused on different stages of the human life cycle: gametogenesis, fertilization, embryonic development, fetal development, childhood (including adolescence), and adulthood (including senescence). Their posters were accompanied by activities designed to further engage the senior citizens who visited during a lab period at the end of the semester. While the senior citizens completed surveys, the students wrote short essays reflecting on the value of the project. The surveys demonstrated an increase in the senior citizens' understanding of human development and of current issues related to the discipline. The students' essays revealed that the project was beneficial for many reasons, most notably because it fostered a sense of civic responsibility among the next generation of scientists.

Introduction
Civic engagement is a pedagogical strategy that is successfully employed in a variety of educational contexts (Colby et al. 2003). It is particularly well suited for undergraduates, including those at liberal arts institutions, where the mission often encourages interdisciplinary integration of skills and knowledge to engage with critical issues facing society. The incorporation of civic engagement into specific courses has reciprocal benefits for the students and the local, national, or even international communities to which they belong. Students gain critical insight into specific topics addressed in their coursework while also developing a sense of civic responsibility. In turn, communities may receive benefits when projects promote "quality of life" as envisioned in one definition of civic engagement (Ehrlich 2000). Such projects usually focus on important issues including, but not limited to, poverty, hunger, disease, voter registration, and environmental contamination; moreover, they impact a variety of constituencies, ranging from individuals to groups such

as agencies, businesses, and non-profit organizations. While civic engagement manifests itself in diverse ways, there are some common themes, such as clearly defined learning goals and the opportunity for students to reflect carefully on the educational value of the experience. In many cases, academic credit is based on learning and not the on outcome of the project itself (Howard 1993).

Civic engagement is often discussed in the context of coursework in the social sciences. However, it has been argued that it is equally important that such pedagogy be implemented in the natural sciences, for a variety of reasons (Kennell 2000). For example, the projects can provide students with a better sense of how their acquired knowledge is, in fact, relevant to "the real world." The projects can also help to educate citizens in the local community who have little or no background in the natural sciences, but who must often vote on issues related to the use of stem cells in regenerative medicine, the protection of organisms from the effects of climate change, and the creation of genetically engineered organisms to deal with agricultural pests. In fact, the estimated percentage of citizens who are "scientifically literate" is only 28 percent in the U.S. (Raloff 2010). In addition to promoting scientific literacy, the projects can help to demystify the process by which scientists collect and analyze data, which is important given the results of recent surveys reported by the National Science Board (2012). A variety of effective projects have already been implemented by scientists, including one in which students used emerging technologies as tools in projects related to environmental sustainability and designed to meet the specific needs of their community (e.g. an interactive trail map for a nature preserve prepared using GIS) (Green 2012). In the case of this particular project, the faculty member asked the students to complete surveys, provide anonymous feedback, and write an essay reflecting on their experiences. This project and others provided the inspiration for my own recent initiatives to incorporate civic engagement into advanced biology coursework.

Description of the Service Learning Project

I have incorporated a civic engagement project into a developmental biology course at Denison University, a small liberal arts institution in Granville, Ohio. An undergraduate course in developmental biology usually focuses on model systems—the fruit fly, frog, and chicken, for example— from which biologists have gained insight into the molecular basis of human disease and development. Fertilization, cleavage, and gastrulation are quite complex; accordingly, instructors usually devote several weeks to these earliest stages of embryonic development. In the absence of conversations about issues like stem cell research, however, it is easy for students to lose sight of the "big picture." I therefore decided to design a project that would allow students to "come full circle" at the end of the semester by having them engage in a conversation about the human life cycle with local senior citizens. I chose to have the students work with senior citizens since many of the campus outreach programs are focused on local youth. In addition, I expected that the senior citizens would have many interesting, relevant experiences to share with the students, and that they would be a more appropriate audience given the nature of the course material.

For the project, I divided my 24 students into six groups, each focusing on one stage of the human life cycle: gametogenesis, fertilization, embryonic development, fetal development, childhood (including adolescence), and adulthood (including senescence). I provided each group with a poster template with three sections titled "Concept," "Concept Explained," and "In the News." In the "Concept" section the students defined their stage in no more than two or three sentences, while in the section titled "Concept Explained," the students provided more detailed information and, in some cases, divided their stage into several distinct steps (e.g. sperm attraction, acrosome reaction, fusion of the plasma membranes, prevention of polyspermy, activation of egg metabolism, and fusion of the genetic material, in the case of fertilization). Finally, in the section titled "In the News," the students provided information on one recent issue, debate, or controversy related to their stage (in the case of fertilization, for example, the availability of a male contraceptive). In addition to the poster, I asked the students to develop a simple activity to further engage their audience. I provided them with a few ideas—completing a quiz, watching a short video on a laptop, and examining eggs, embryos, and/or larvae under a microscope—although I encouraged the students to think creatively about other options to facilitate learning. As the final component of the project, the students wrote a short essay on the value of civic engagement in the context of a liberal arts education and one thing they learned from their interactions with senior citizens. I was particularly interested in having them reflect on the value of this educational strategy in the natural sciences.

Other than providing them with a poster template, I offered little or no guidance to the individual groups; the students assumed responsibility for their poster displays as well as for the tasks required to prepare for the arrival of the senior citizens. During their visit, student volunteers escorted the senior citizens from one station to the next, giving them at least ten minutes to learn about each stage of the human life cycle. In many cases, the senior citizens were so engaged with the material that they remained at a station for much longer in order to ask questions and/or have an extended conversation with the students. The students ensured that there was sufficient seating in front of each poster display, since many of the senior citizens spent a total of about two hours rotating through the different stations. They had learned about this opportunity through an e-mail sent to retired staff or through an advertisement in the local newspaper, although a few were recruited from a local senior center by the John W. Alford Center for Service Learning at Denison. Snacks were purchased from the Smiling with Hope Bakery, which is run by special-needs students at Newark High School in Newark, Ohio.

Outcomes of the Service Learning Project

In an effort to assess the senior citizens' learning, I prepared a short survey in which they rated their understanding of 1) human development, and 2) current issues in developmental biology both before and after visiting the poster displays. A total of 17 local senior citizens were recruited for the project, with thirteen of them completing the survey at the end of the afternoon (Table 1). In both cases, there was a statistically significant increase in their understanding, with several individuals offering positive comments about the experience, either through e-mail or through comments at the bottom of the survey. Indeed, students noted in their essays that the senior citizens were "focused," "inquisitive," and "enthusiastic," with "a genuine interest in learning." As the afternoon progressed, I came to realize that the senior citizens were modeling the idealistic concept of "lifelong learning" for my students through their intellectual engagement (McClure 2013).

To assess the students' learning, I evaluated their poster displays and the essays that they wrote following the senior citizens' visit. Since this was a pilot project, each component was worth only five percent of their final grade in the course. As I had expected, many students indicated that teaching what they had learned in the course helped them to gain a more complete understanding of important concepts in developmental biology. On a related note, they recognized civic engagement as an effective strategy to improve upon their communication skills. Many students also appreciated the opportunity to leave the "bubble" of campus life and interact with members of the local community, while learning how to "effectively converse [with them] about key issues facing society." However, the students' essays revealed that the project was beneficial in ways that I could not have predicted. For example, many students described their initial uncertainty about the value of civic engagement, but then wrote about how they came to view it as an "innovative way to incorporate many themes from our mission statement" and "a prime example of the types of endeavors [the institution] should continue to pursue to more fully provide its students with a liberal arts education." They recognized it as an opportunity to "interact with diverse groups of people" and to "facilitate [their] growth into change makers that will work to fix the problems faced by humanity." Several of them even described how rewarding it was to communicate knowledge with those who may not have had the opportunity to pursue an undergraduate education, noting their status as "privileged students," who have a responsibility to "share [their] experience with others."

Conclusions

I was quite satisfied with the extent to which the students reflected on the project and expressed "joy" (in their own words) in having the unique opportunity to engage with the local community as part of a biology course. In the future, I hope that this project will be extended to senior citizens from more impoverished communities, perhaps with students actually meeting them at a retirement facility. In addition, I hope to design alternative projects that address senior citizens' specific interests (besides the human life cycle), since some of our visitors indicated on their surveys that they wanted to learn more about such topics as environmental influences on aging. And finally, I hope to encourage my peers to consider incorporating

TABLE 1. Mean responses on pre- and post-surveys administered to senior citizens participating in the service learning project.

On a scale of 1 (low) to 5 (high), rate your...	pre	post	$t_{20.86}$	p
1. Understanding of human development.	3.54	4.27	-3.32	0.0032*
2. Understanding of current issues in developmental biology.	2.92	4.00	-3.27	0.0041*

a civic engagement project into their own courses, since this educational strategy obviously has much to offer to students in the natural sciences, even in the realm of cellular and molecular biology. It can be easily accomplished during a single lab period, although it can be more extensive with activities spanning one or more semesters (e.g. Hark 2008; Imoto 2013; Larios-Sanz et al. 2011; Santas 2009). Regardless of the size and scope of the project, civic engagement can transform students' thinking and inspire them to make important contributions to the world, whether as a nurse, teacher, or conservation biologist. It should be an integral component of every academic institution, "across all fields of study" as the National Task Force on Civic Learning and Democratic Engagement has declared (2012). In summary, I would argue that scientists have an important role to play in developing students' sense of civic responsibility in the 21st century.

About the Author

Laura Romano is an Associate Professor in the Department of Biology at Denison University in Granville, OH. She earned her BS in Biology from the College of William and Mary, and her PhD from the University of Arizona. She also completed three years of postdoctoral research at Duke University. She teaches introductory biology courses as well as advanced courses in developmental biology and invertebrate zoology. In addition to teaching, she enjoys advising students and mentoring them in her laboratory where she studies the evolution of developmental mechanisms using the sea urchin as a model system.

References

Colby, A., T. Ehrlich, E. Beaumont, and J. Stephens. 2003. Educating Citizens: Preparing America's Undergraduates for Lives of Moral and Civic Responsibility. San Francisco: Jossey-Bass.

Ehrlich, T. 2000. Civic Responsibility and Higher Education. Phoenix: Oryx Press.

Green, D.P.J. 2012. "Using Emerging Technologies to Facilitate Science Learning and Civic Engagement." Science Education and Civic Engagement 4 (2): 18–33.

Hark, A. 2008. "Crossing Over: An Undergraduate Service Learning Project that Connects to Biotechnology Education in Secondary Schools." Biochemistry and Molecular Biology Education 36 (2): 159–165.

Howard, J. 1993. "Community Service Learning in the Curriculum." In Praxis 1: A Faculty Casebook on Community Service Learning, J. Howard, ed., 3–12. Ann Arbor: OCSL Press.

Imoto, D. 2013. "Service-learning in an AIDS Course." Science Education and Civic Engagement. 5 (1): 25–29.

Kennell, J. 2000. "Educational Benefits Associated with Service-learning Projects in Biology Curricula." In Life, Learning, and Community: Concepts and Models for Service Learning in Biology, D. Brubaker and J Ostroff, eds., 7–18. Sterling, VA: Stylus Publishing, LLC.

Larios-Sanz, M., A. Simmons, R. Bagnall, and R. Rosell. 2011. "Implementation of a Service-learning Module in Medical Microbiology and Cell Biology at an Undergraduate Liberal Arts University." Journal of Microbiology and Biology Education 12 (1). http://jmbe.asm.org/index.php/jmbe/article/view/274/html_100 (accessed July 9, 2014).

McClure, A. 2013. "Promoting the Liberal Arts." University Business. http://www.universitybusiness.com/article/promoting-liberal-arts (accessed July 9, 2014).

National Science Board. 2012. Science and Engineering Indicators 2012. Arlington, VA: National Science Foundation.

National Task Force on Civic Learning and Democratic Engagement. 2012. "A Crucible Moment: College Learning and Democracy's Future." Washington, DC: Association of American Colleges and Universities.

Raloff, J. 2010. "Science Literacy: U.S. College Courses Really Count." ScienceNews. https://www.sciencenews.org/blog/science-public/science-literacy-us-college-courses-really-count (accessed July 9, 2014).

RESEARCH PAPER

Science Bowl Academic Competitions and Perceived Benefits of Engaging Students Outside the Classroom

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Abstract

The National Science Bowl® emphasizes a broad range of general and specific content knowledge in all areas of math and science. Over 20,00 students have chosen to enter the competition and be part of a team, and they have enjoyed the benefits of their achievements in the extracurricular Science Bowl experience. An important question to ask, in light of the effort it takes to organize and participate in regional or national science competitions, is whether the event makes a difference to the student. And if it does make a difference, does it improve student learning or student attitudes about science? In a preliminary survey, students competing in a Regional Science Bowl Competition report that the event has a positive impact and fosters learning in science and mathematics. These data support findings for other forms of extracurricular academic competitions associated with science and mathematics.

Introduction

Since 1991, the Department of Energy's (DOE) National Science Bowl® has been sponsoring annual regional and national competitions for high school students across the United States of America, including Puerto Rico and the U.S. Virgin Islands. In addition to seeing the pragmatic value of increasing the "feed" of science-educated personnel into DOE research facilities, the DOE recognized that the improvement of science education, broadly, would be of great benefit to the nation. Expanding its focus beyond formal science education at the college level, the DOE started the Science Bowl program to encourage high school student participation and interest in math and science. The idea was to increase science literacy in general and to encourage science- and mathematics-related careers specifically. The success of the high school competitions resulted in the expansion of the program to include middle schools in 2002.

The competitions feature teams of four to five students answering multiple choice and short answer questions in the areas of science, mathematics, energy, and technology. There are currently 67 regional high school and 36 middle school competitions. The high school competitions involve more than 15,000 students and the middle school contests more than 6,000. The winning team from each regional event is invited to Washington D.C. to compete with other winners.

Participation in Science Bowl involves working as a team, and a team's level of success is determined not only by scientific knowledge, but also by teamwork and gamesmanship. The students' engagement in group work directly benefits the individual team members, their social groups, and society as a whole (Greif and Ephross 2011, 6). The actual team formation and function is itself a model for both future community engagement and civic activism. In fact, creating teams is one of the three principal strategies for successfully placing students in service-learning opportunities within communities. (Harris 2009).

The National Science Bowl® emphasizes a broad range of general and specific content knowledge in all areas of math and science. Science Bowl experiences are independent of the classroom environment and generally occur because the students have volunteered to enter the competition and become part of a team. Each team must have a coach, who can be a parent or other interested person, but is usually a high school science teacher. The volunteer aspect of the competition as an extracurricular activity means that it is similar to robotics competitions, the Science Olympiad, and other interdisciplinary, multi-disciplinary, and applied endeavors. All of these programs stress the collaborative and communal nature of the projects over the content, a characteristic shared by other civic engagement and volunteer endeavors (Jacoby and Ehrlich, 2009).

An important question to ask in light of the effort it takes to run regional or national science competitions is whether the event makes a difference to the student. And if it does make a difference, does it improve student learning or student attitudes about science? The literature on science competitions is not extensive. Abernathy and Vineyard (2001, 274) asked students who competed in the Science Olympiad why they did so. The number one reason for participating in the Olympiad was that it was fun. The number two reason was that the participants enjoyed learning new things. These findings held for both male and female participants; they seemed to think learning science and math in this context was enjoyable. Abernathy and Vineyard suggested that competitive events "may be tapping into students' natural curiosity and providing a new context for them to learn in, without rigid curriculum or grading constraints (2001, 274)."

Competitive events such as the National Science Bowl® may provide the "initial motivation" and catalyst for helping students to discover the joy of learning (Ozturk and Debelak, 2008). Academic competitions can provide motivation for students to study, learn new material, and reinforce previously learned material so that they will be ready to compete (and collaborate) with their peers from other schools both regionally and nationally—not just in games but also in academic and work environments. This type of motivation is difficult to provide in a normal classroom environment. While it can be argued that this is solely extrinsic motivation and that students should not be dependent on it, it can nevertheless serve as the spark that ignites a discovery of the joy of learning science and math.

One of the more important effective benefits of competitions like the National Science Bowl®, is that the participants, who may be the academic elite at their home schools (big fish in a little pond), must test their knowledge and skills against the students from other schools who will be their peers once they get to college and the workplace. Ozturk and Debelak (2008) note that students "learn to respect the quality of work by other children and to accurately assess their own performance in light of the performance of their intellectual peers. They achieve an accurate assessment of where their level of performance stands in the world of their intellectual capacity and, in turn, develop a more wholesome self-concept" (51) . Developing a more accurate and grounded self-concept is an important stage for children to go through on their way to becoming healthy and mature adults. This realistic and comparative self-assessment can be difficult to foster in the case of elite students who have never faced stiff competition or external challenges to their academic abilities in their home institution.

Students in academic competitions also benefit from learning not only how to succeed, but how to accept failure, learn from it, and, "subsequently, grow as a person and improve in performance" (Ozturk and Debelak 2008, 52). This, again, may be one of the most important aspects of intramural academic competitions, one that cannot be easily provided in a typical classroom environment; learning to fail and being able to cope with the emotional aftermath may be riskier in a classroom environment than in a games environment where the experience of failure is shared among the group. Being thrust into a situation where participants must deal with failure (even after they have prepared and done their best) promotes the healthy development of a student's resilience and self-awareness. Academic competitions like the National Science Bowl® and its many regional competitions may provide the type of environment that helps students to reflect on their knowledge and abilities and self-evaluate their performance, promoting improved personal growth and development for the participants.

Certainly, extreme competitiveness can cause anxiety and undue stress (see for example Davis and Rimm, 2004). Many of us can remember learning in our Psychology 101 course about test anxiety and how it can negatively affect student performance and achievement and lead to low self-esteem. But Davis and Rimm also report that competition can increase student productivity and achievement. Some students seem to need to compete with others in order to push themselves to produce at a higher level. It would follow that socially organized competitions like the National Science Bowl® and its many regional competitions could help to promote high levels of achievement and productivity in the participating math and science students. Some of the increased levels of achievement and productivity may be due to the practice in teamwork and study skills promoted by participation in this type of academic competition. Bishop and Walters (2007) report that the students involved in competition increased their ability to be leaders and team players, especially in the areas of directed studying ("cramming"), communication, and stress management.

Most studies of this nature tend to be based on student reporting of their own perceptions, and Bishop and Walters also discuss the viability of using a self-report, Likert scale survey to investigate how the National Ocean Sciences Bowl (NOSB) influenced the participants' choice of major and courses in college. They further triangulate their data using follow-up interviews, information on the colleges the students attended, and lists of the college courses the students took following their participation in the NOSB. Their longitudinal study, which took place from 2000–2007, establishes the credibility of the students' self-reported data using this type of survey (Bishop and Walters 2007).

What Do the Students Get from This Competition?

A brief survey was developed for the students who compete in the Northern New England Regional Science Bowl Competition, for the purpose of gathering information about the students' perception of the impact the competition has on them and other students. The questions were developed by the Regional Science Bowl coordinators and distributed to the students (also to coaches, volunteers, and audience) on the actual day of the competition, which takes place each year in late February or early March. The students in the Northern New England Regional Science Bowl Competition come from the three northernmost New England states, Maine, Vermont, and New Hampshire. The competition is an extracurricular activity; the students in grades 9–12 have self-selected to be part of a team that practices and competes during non-school hours. The students making up the teams tend to be academically successful. As might be expected, these students usually like mathematics and science and are predisposed to participate in activities involving these subjects. The teams of students compete in a one-day event at the University of Southern Maine, which culminates in a single elimination tournament round. The winning team is offered an all-expenses-paid trip to Washington D.C. to compete with other regional winners for the national championship. Students at the regional bowl are given the survey. Completing and returning the survey is voluntary, although the students and coaches are made aware that their responses will help improve the event.

The Instrument

The first part of the survey was designed to collect general background information about the students and their role in the day's competition. This section was a simple checklist:

This is my first experience.

I've been at previous science bowls here.

I was a volunteer today.

I am a spectator/guest.

I was one of the student competitors today.

I am a coach of one of the teams.

The next set of items was intended to gain insight into the students' perceptions of how the regional competition affected the students who were taking part in the day's activities and events. The questions consisted of three Likert-type response choice items:

1. I think this competition had a positive impact on the students:

2. Quiz competitions foster student learning about science and mathematics:

3. Quiz competitions are stressful in a negative way:

Each of these questions had a five-choice scale that ranged from strongly agree to neutral to strongly disagree. There were also two open ended questions:

The thing I enjoyed most about today was:

What I would recommend for next year:

And finally a yes/no question:

I'd like to come back next year.

Findings and Discussion

Data collection began with the 2004 Northern New England Regional Science Bowl Competition and continued through 2009. (After this year the Bowl was restructured and focused exclusively on Maine students, although participants continue to be surveyed.) This six-year longitudinal study has provided data representing a constant mix of new and returning students. Throughout the course of the study, there was an almost equal distribution of first-time and returning students who responded to the survey. Although the survey was distributed to students, coaches, and other volunteers who took part in the events, only the results of the student surveys were used as part of this report. The voluntary nature of conducting the study produced an average of fifteen percent of the students per year completing and returning the survey. Interviews with coaches and students indicate that the low response rate is most likely a result of its collection at the end of a long, intense day, when many teams were eager to start their journeys back to homes throughout northern New England.

Of the students participating in the Northern New England Science Bowl who responded to the survey during the study period, 93 percent either agreed or strongly agreed that the competition had a positive impact on them (Table 1).

Campbell and Walberg (2011) suggest that this type of positive impact follows the students throughout their life. Willingness to participate in events on their own time, especially during the weekend, demonstrates a high level of positive engagement that would foster feelings of positive impact. Akey (2006,16) reports that "student engagement and perceived academic competence had a significant positive influence." on achievement. The survey results also suggest that the students perceive themselves as academically competent in math and science, and that is why they participate. This mirrors the findings of Abernathy and Vineyard (2001) who report that academic competitions tap into the natural curiosity and inclinations of students and provide an arena for them to learn new things. The science bowl event could provide the platform for these students to excel and receive recognition. Further, Ozturk and Debelak (2008) report that academic competitions may provide the motivation to find the joy in learning. Curiosity and motivation are important aspects of learning that would presumably have a positive impact on the lives of the participants in academic competitions like the National Science Bowl®.

Most (91 percent) of the respondents reported either that they agreed or that they strongly agreed that the Regional Science Bowl Competition fosters student learning in science and mathematics (Table 2).

TABLE 1. Table 1: Perception of positive impact of competition. Based on a 5 point Likert scale with 5 being the highest.

Year	2004	2006	2007	2008	2009
Mean	4.1	4.7	4.8	4.3	4.7
SD	.60	.42	.40	1.1	.45

TABLE 2. Agreement that the Science Bowl Competition fosters student learning in science and mathematics. Based on a 5 point Likert scale with 5

Year	2004	2006	2007	2008	2009
Mean	3.9	4.6	4.8	3.8	4.6
SD	.98	.49	.40	.98	.49

These data again appear to support the research done by Abernathy and Vineyard (2001), indicating that academic competitions provide a forum to stimulate the students' natural curiosity about learning new things, as well as the work of Ozturk and Debelak (2008), who have concluded that academic competitions may motivate students to discover the joy of learning.

The high positive response rate of these two questions indicates that the student participants in the Regional Science Bowl Competition are developing a strong positive sense of self. These responses, reinforced by our interviews of participating coaches, indicate that the students are reflecting on their experiences and developing a more complete self-image and perhaps an increased sense of their personal competence. Bishop and Walters report that an enhanced and comparative sense of personal competence or capability "translates as a very high factor influencing career choice" (2007, 69). It may well be that academic competitions such as the National Science Bowl® and its associated regional competitions provide experiences that positively influence student career choices.

Interestingly, the same students who reported that the Science Bowl Competition had such a positive effect on them in general, and a positive effect on their learning, did not necessarily think the competition was unstressful. Only 61 percent disagreed or strongly disagreed that the quiz competition was stressful in a negative way (Table 3).

Perhaps the wording of the question led students to equate "quiz" with "test," which affected their response. It could also be that the students consider any kind of stress negative, and if they perceived that the competition created even a low level of stress, they would conclude that this was a negative effect.

In the open-ended question that asked what they enjoyed the most about the Science Bowl, the number one response was competition, the second most frequent response was meeting like-minded people, and the third was the hands-on nature of the activities. These students seem to be saying that they feel that testing their knowledge and skills in science and mathematics against other students of similar ability is fun! Maybe this is because they are beginning to form a deeper understanding of and respect for the quality of their work, as suggested by Ozturk and Debelak (2008). Academic competitions (such as the Science Bowl) may give students the opportunity to compete mentally the way athletic competitions allow them to compete physically (Parker 1998). Perhaps these students get the same kind of "high" that athletes get during competition, and the thrill of academic competition releases endorphins much the same way that athletic competition does.

The data indicate that a statistically significant portion of the students competing in the Northern New England Regional Science Bowl Competition report that the event has a positive impact on them and fosters learning in science and mathematics. These data support findings that have been reported for other forms of academic competitions that are involved with science and mathematics (e.g. Campbell and Walberg 2011). Self-reporting indicates that the students have a high level of perceived personal competence, a high level of

TABLE 3. Perception of Science Bowl Competition as stressful in a negative way. Based on a 5 point Likert scale with 5 being the highest.

Year	2004	2006	2007	2008	2009
Mean	2.3	2.0	2.1	2.6	2.1
SD	.79	.69	1.17	1.02	1.1

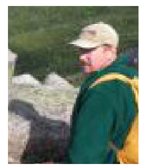
engagement in mathematics and science activities, and a high level of motivation toward these academic subjects. In addition to increased involvement in the community, competence, engagement, and motivation are factors that have been linked to academic achievement, personal growth, and career choices. If the education community is seeking to increase student interest and participation in science and mathematics majors and in science and mathematics careers, and ultimately in complex science-related public policy discussions, then academic competitions like the National Science Bowl® may be an important part of the overall strategy bringing the nation closer to that goal.

A Proposal for Further Study

A key aspect of the Science Bowl competition is its role in building a social community of contestants, which leads one to wonder whether the competitions contribute to increased involvement in the larger community and whether they encourage participants to become more effective and engaged citizens. Participating schools are likely to return to the event, as are alumni who come back as volunteer officials. Further, with the release of recent studies, such as "Steady as She Goes? Three Generations of Students through the Science and Engineering Pipeline" (Lowell et al., 2009), we (the authors of this paper) feel an ethical responsibility to continue the investigation of whether science competitions represent meaningful contributions to the experience of students and their disposition towards science.

To better understand the impact of the Science Bowls on both STEM learning and civic engagement, we recommend that surveys be administered for all the National Science Bowl® middle school and high school competitions. The surveys should be standardized, with optional regionally based questions, and should be part of a well-designed study that can inform future science bowl decisions. An existing instrument, the Student Assessment of Learning Gains (SALG, http://www.salgsite.org/), has survey questions that are geared towards formal academic courses but are a no-cost, accessible means to obtain data on students' attitudes about science. Social media also provides opportunities for assessment and self-reporting of students. Surveys can be followed up by focus group interviews that could provide greater depth to our understanding of the findings. Such longitudinal studies could serve to verify whether or not these informal and volunteer learning experiences correlate with continued interest and involvement in science and mathematics, including choice of college majors, careers, and enhanced awareness and involvement in our most pressing science-related civic challenges, including climate change, public health, and technology.

About the Authors



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References

Abernathy, T., and R. Vineyard. 2001. "Academic Competitions in Science: What Are the Rewards for Students?" The Clearing House 74 (5): 269–276.

Akey, T.M. 2006. School Context, Student Attitudes and Behavior, and Academic Achievement: An Exploratory Analysis. New York: MDRC. http://www.mdrc.org/publications/419/full.pdf. (Accessed July 7, 2014.)

Bishop, K., and H. Walters. 2007. "The National Ocean Sciences Bowl: Extending the Reach of a High School Academic Competition to College, Careers, and a Lifelong Commitment to Science." American Secondary Education 35 (3): 63–76.

Campbell, J.R., and H.J. Walberg, 2011. "Olympiad Studies: Competitions Provide Alternatives to Developing Talents That Serve National Interests." Roeper Review 33:8–17.

Davis, G.A., and S.B. Rimm, 2004. Education of the Gifted and Talented. 5th ed. New York: Pearson.

Greif, G., and P. Ephross. 2011. Group Work with Populations at Risk. Oxford: Oxford University Press.

Harris, J.D. 2009. "Service-learning: Process and Participation." In Service-learning and the Liberal Arts, C.A. Rimmerman. ed, 21–40. Lanham, MD: Rowman & Littlefield.

Jacoby, B., and T. Ehrlich, eds. 2009. Civic Engagement in Higher Education. San Francisco: Jossey-Bass.

Lowell, B.L., H. Salzman, H. Bernstein, and E. Henderson. "Steady as She Goes? Three Generations of Students through the Science and Engineering Pipeline." Paper presented at the Annual Meetings of the Association for Public Policy Analysis and Management, Washington, D.C. http://policy.rutgers.edu/faculty/salzman/steadyasshegoes.pdf. (Accessed July 7, 2014.)

Ozturk, M., and C. Debelak. 2008. "Affective Benefits from Academic Competitions for Middle School Gifted Students." Gifted Child Today 31 (2): 48–53.

Parker, S. 1998. "At Dawn or Dusk, Kids Make Time for This Quiz." Christian Science Monitor 90 (116): 49–54.