WHITE PAPER

EXPANDING QUANTITATIVE ANALYSIS AS A FRAMEWORK FOR INTERDISCIPLINARY LEARNING AND APPLIED PROBLEM SOLVING

Submitted by: WHEATON COLLEGE

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INTRODUCTION

The Working Group at Wheaton College engaged in a 20-month program that focused on Quantitative Analysis based on our belief that liberal arts colleges can play an important role in addressing problems related to the erosion in math and science proficiency in the United States. We view this as an important undertaking given how swiftly the global landscape is changing, especially in relation to advances in science and engineering in China and India. Our premise is that Wheaton, and by extension other liberal arts colleges, can ensure that quantitative reasoning is integrated more effectively and more comprehensively within the curriculum because faculty members are committed to creating content that is challenging, motivating, and relevant; they provide more personalized research opportunities for students; their orientation is toward sustained mentoring relationships; and they are engaged in community-wide dialogues among faculty, students and staff to incorporate mathematical concepts and applications into the overarching goal to teach students critical thinking and lifelong learning skills.

As professors of mathematics, we believe an understanding of quantitative analysis and quantitative literacy is essential for comprehending the data that describe life’s intellectual, economic, and political realities. We teach concepts and skills that establish a framework for evaluating relationships between entities, for understanding perspective, and for interpreting change in spatial and temporal terms. We acknowledge that successfully conveying this abstract and applied knowledge to faculty in other disciplines as well as students is often a daunting and frustrating task given the math phobia that permeates our culture. This White Paper summarizes the work we undertook to improve how quantitative analysis is taught at Wheaton and to underscore how the new focus on numerical literacy provides the foundation upon which all students can develop increased competency in all disciplines.

OBJECTIVES

The Working Group at Wheaton College introduced creative and stimulating ways to engage students as intentional learners in the realm of quantitative analysis through its course connections curriculum. This gives students the opportunity to approach the same topic from different academic perspectives while also creating connections among classroom learning, internships, and research opportunities. As part of...
Wheaton’s curricular transformation, 2006-2007 was dubbed the Year of Quantitative Analysis during which time new pedagogical approaches were used; campus-wide and external collaborations were emphasized; and various activities, exercises, and displays were offered to instill interest, improve performance, and engage faculty and students to pursue quantitative analysis knowledge and skills more aggressively and successfully at Wheaton College that will have merit as a model for liberal arts education.

The Working Group consisted of a core of three professors: William Goldbloom-Bloch, Professor of Mathematics and Associate Provost, Tommy Ratliff, Chair and Associate Professor, Department of Mathematics and Computer Science, and Michael Kahn, Professor of Mathematics and Director of Quantitative Analysis. They worked with faculty and students from a range of departments, the head of the College’s Multicultural Center, and a number of external advisors. The work was organized as follows:

- Increase the number of course connections with links to quantitative analysis
- Expand and enhance the peer tutoring activities in the QA Resource Center
- Develop a Math Consulting Program with teams of faculty and students to work with local and regional businesses and industries on research projects that demand mathematical solutions—This was a major component of the QA Working Group initiatives and it had a huge impact on our program. It is also the most easily reproducible and transferable program to other liberal arts colleges. See Report beginning on page 8 of this White Paper.
- Invite Wheaton faculty and external speakers to lecture on QA topics at Wheaton College
- Offer math-centric events for students and the local community
- Assess and evaluate the impact of the above activities to improve how quantitative analysis is understood and to gauge any changes in the number of math majors and math minors and non-majors in course connections that feature math courses.

**METHODOLOGY**

**QA in the Wheaton Curriculum Via Course Connections**

Wheaton adopted a creative and stimulating approach to engage students as intentional learners in the realm of quantitative analysis as part of its bold curricular reform, approved overwhelmingly by a faculty vote of 91-3 in December 2001 for the entering class of 2003. This curricular redesign was based on the recognition that disciplinary boundaries are blurring and new methods and topics of inquiry are emerging beyond those boundaries. One component of the curriculum includes designing connections between two or more courses linked across disciplines to give students the opportunity to approach the same topic from different academic perspectives while also creating connections among classroom learning, internships, and research opportunities. The benefits of such cross-fertilization yield a far richer, more satisfying, complex, and ultimately more effective educational experience for both students and faculty.
We emphasize the interdisciplinary aspect by dividing our courses into six distinct areas: History, Creative Arts, Humanities, Natural Sciences, Social Sciences and Math/Computer Science. A Connection consists of two or three courses that have intersections and commonalities that have been linked together by faculty in at least two areas. After musing about how the courses relate and what sorts of joint projects, activities, lectures or common readings the Connection may share, faculty submit a proposal to the Educational Policy Committee for vetting and approval.

Learning quantitative skills and judgment in this connected context helps provide the necessary balance between life-long learning skills and content knowledge. Currently one-fifth of the Connections include a Math/Computer Science course. The connected courses are descriptive of the breadth and depth of this educational tool relative to the mastery of mathematics and quantitative analysis:

**Communicating Information:** Connects Math, *Discrete Mathematics* with English, *Professional and Technical Writing* to convey how language and logic, in both courses, are a means of learning material, developing thinking processes, and solving problems—all of which are inherent to organizing and communicating information. Group problem solving and collaborative communication are employed to explore the visual display of quantitative information as students read and design charts, graphs and/or figures.

**Communicating Through Art and Mathematics:** Connects Art *Graphic Design* and Math *Colorful Mathematics* to expand the idea that effective design layout enhances communication, particularly as it is used in advertising. Topics that link math and computer graphic 3-D representation are incorporated into the course and students use this and other tools to create an advertisement for math that includes prose, verse, song, drawing, graphics and/or other media.

**Computer Architecture:** Connects Computer Science *Computer Organization and Assembly Language* and Physics *Electronic Circuits* to yield practical experience and knowledge through creating electronic circuits with a theoretical understanding of how data are stored and transmitted within the structure of a computer.

**Computing and Texts:** Connects English *Anglo-Saxon Literature* or *J.R.R. Tolkien* with Computer Science *Computing for Poets* to demonstrate how computing can be used to investigate textual corpora (specifically the Dictionary or Old English machine-readable corpus of Anglo-Saxon and Professor Drout’s electronic corpus of the writings of J.R.R. Tolkien). Students use techniques such as word-frequency counts to investigate and characterize authorship, prose and poetic style, and the dating of text while they learn to design introductory experiments, write programs and software to search textual corpora and gather statistical measures. There is a similar Connection titled *Poetry and the Computer* that links *Computing for Poets* with *Early Modern English Poetry*.

**Ecology: A Statistical Approach:** Connects Biology *Ecology* with Math *Accelerated Statistics* to equip biologists with applied statistical techniques from experimental design to data analysis. Ecology is a science that is defined largely by field-collected data, thus there are numerous sources of variability. Computers permit sophisticated and robust statistical
procedures to be applied to large field-generated data sets to filter through the “noise” to obtain a valid “signal” that will drive the questions asked and conclusions reached. This connection grew out of classroom visits during which math professors helped in analyzing data on characteristics of trees using negative correlation, scatterplots, and regression analyses to reveal surprising aspects of the objects of study and interesting, unsuspected correlations as well as used differential equations to provide rough models of environmental interactions, such as the predator/prey relationship. It is likely that Calculus II will be added to this Connection.

Encoding Text, Revealing Meaning: Connects Computer Science Computing for Poets, History U.S. Women 1790-1890, First Year Seminar Exploring New Worlds in Old Books, Hispanic Studies Voyages, Navigations, and Shipwrecks to “get inside” a 16\textsuperscript{th} or 17\textsuperscript{th} century book by transcribing, studying, researching, editing, and encoding the text in a digital version. By producing hyper-textual editions that can be accessed online, complete with annotations, pictures, maps, etc. other readers can track various individuals’ perspectives on how they interpreted the text using tools from the Text Encoding Initiative (TEI).

Genes in Context: Connects Biology DNA or Cell Evolution or Genetics, Computer Science DNA or Algorithms with Philosophy Ethics to explore how the technology and medicine related to DNA have generated a wide range of ethical implications. Students learn Perl, deemed by many in bioinformatics to be one of the more accessible string-matching languages, useful for genome searches and pattern matching for phylogenetic trees.

Graphic Design and Web Programming: Connects Computer Science Web Programming, Graphics and Design and Arts Graphic Design to teach basic graphic design principles and computer programming to build Web pages that incorporate interesting graphics, animation and dynamic content.

Learning to Learn in Math and Science: Connects Education Early Childhood Curriculum or Elementary Curriculum with Interdepartmental Ponds to Particles and Math Concepts of Mathematics to address issues in the nature and quality of math and science education with a view towards equipping education majors with appropriate pedagogies and to emphasize confidence building as science learners and educators.

Logic and Programming: Connects Philosophy Logic and Computer Science Robots, Games and Problem Solving to establish a context for using logical equivalence, propositional expressions and clear reasoning to write computer programs or software.

Mathematical Tools for Chemistry AND Mathematics of Chemical Analysis: These two connections link Physical Chemistry with Linear Algebra or Multivariable Calculus AND Analytical Chemistry with Accelerated Statistics to teach the mathematical representation of molecular behavior or the composition of a chemical sample.

Quantum Theories: Contemporary American Fiction, Modern Physics and the Universe: Connects English Contemporary American Fiction: Quirks, Quarks, and Quests or Sex, Lies, and Quantum Leaps with Physics Modern Physics or Astronomy The Universe to provide context for the use of language, counter-intuitive notions about cause-and-effect logic, the
posing of images and metaphors to describe quantum theory and the relationship of electrons, particles, waves, fields, antimatter, quarks, and pulsating flux; all framed using statistical tools and techniques. This connection resulted from discussions between two professors in the English and Math departments on how to convey these difficult concepts; a book on this subject is forthcoming.

Science FACTion: Connects Math The Edge of Reason and English Science Fiction to introduce students to the beauty and power of mathematics and show how concepts of combinatorics, infinity, topology, logic, number theory and cryptography are used in science fiction.

The Calculus of Microeconomics: Connects Math Calculus with Economics Economic Applications and Introduction to Microeconomics to portray graphic representations of marginal analysis, continuity and optimization to better understand consumer behavior and operations of markets for goods and services and for resources.

The Math in Art and the Art of Math: Connects Math, Math in Art and Art History, Great Works to analyze perspective, fractals, symmetry, and the fourth dimension as expressed in art throughout history.

Top Secret: Connects Math, Cryptography and Political Science, United States Foreign Policy, or National Security Policy or Economics, Industrial Organization and Public Policy to allow students to relate the “hows” of encoding secret information to the “whats” and “whys” of doing so in the domains of government and business.


A survey conducted by Brett Consulting Group that evaluated the Connections component of Wheaton’s curriculum over the period 2005-2007 reported that students gain from taking Connections—“whether it is exposure to new ideas or points of view, a better understanding of the relationship between two subjects, or some more fundamental insight about the connectedness of ideas in general. In the best case scenarios, students apply the insights they have gained from Connections to areas outside of academics.” “Much more significant was the impact of Connections on students’ way of thinking both about a liberal arts education in general and about exploration of issues concerning race/ethnicity at least to some extent, with about half of sophomores saying Connections had had an influence on the latter.” Lastly, “for those not majoring in science, science Connections appear to have piqued the interest in the topic (for about half) and in science in general (for about a third). Students report becoming more interested in science when it was connected to something in which they were interested.”
Tutoring: A Successful Model for Facilitating Learning in QA

Students rely strongly on the tutoring provided by the faculty associates and on peer tutors in the QA Resource Center on campus to help them through their math courses as well as allied discipline-specific classes. A common theme that emerged is that there is a need for basic math re-instruction beyond that offered in the first few weeks of Calculus. Many tools that were supposedly learned in high school are not learned or retained and our client departments do not have the time or resources to help their students re-learn basic skills. Similarly, Wheaton offers access to writing associates who tutor students on basic composition skills rather than rely on history professors having to mark down papers or spend class time reviewing usage and composition.

Thanks to $4000 of Teagle funding, we were able to hire four (4) additional QA tutors during the past academic year and provide more training to all the QA tutors on campus. All QA tutors met at biweekly lunches where the agenda included: discussions regarding what works and what does not work during tutoring sessions, facilitating group work, how to handle difficult situations with tutees, and role playing to facilitate good practice in these and other situations. With the additional tutors and the improved training, there was an increase of nearly 30% in tutee attendance, and a similar increase in the average length of time tutees spent at tutoring sessions. The QA tutor training, and the accompanying data-gathering regarding tutees through simple log sheets filled out at the time of entry by each tutee, has become a model for all tutors on campus.

Student Learning in QA from a Multicultural Context

In meetings with Alex E. Vasquez, Associate Dean of the Marshall Center for Intercultural Learning and a group of students and subsequently with ten POSSE students, we posed questions about the context of learning math and QA from various multicultural orientations. General observations included:

They want “useful” and information presented in “context” to other coursework or social functions, although the information could be presented in less serious ways such as cartoons, movies, etc. They seem to like the mechanical, do it ‘til you get it right, but more abstract problems do not interest them. Students appreciate multiple explanations of tricky ideas, certainly for repetition, but even more to see the idea from different angles. They especially like connecting QA information to their passions, including: Facebook, online games, music, and sports. An African-American math major quipped “that he has math on his Facebook page and that people think you’re smart, but not interesting.”

The students expressed a profound appreciation for tutors over professors in helping them pass at least one QA course. Peer tutors are not intimidating, they are willing to work with individual students and small groups for hours and they are on from 8-10 p.m. which is “when the student day is just beginning.” “They are closer to us than really smart professors, so they can dumb down the ideas until they are understandable.” “Often the lag between the last QA class in high school and the first QA class at Wheaton is so long
that it 1) contributes to any previously held insecurities and negative feelings; and 2) entails a huge decay in any previously-learned QA competencies and skills.

Grades are first and foremost in their mind. Students said they would take more math if they were guaranteed a B. They are interested, but can’t afford the low grade. “Auditing sounds great but it’s too much work for too little transcript result.” It was clear that their selection of professor through discussions with other students was primarily “will I get a good grade from this professor?” On a related topic, students want smaller classes; a feeling that professors really care about them and how they are doing. “I was one person of 38 and felt like I was the only person who didn’t understand. In a small class, it feels like we’re having a dialogue, and I can interrupt and ask questions.”

A Course in Mathematical and Statistical Consulting

Vision and Initial Obstacles
During the last few years, the members of the Mathematics and Computer Science Department at Wheaton recognized a lack of applied opportunities for students. Michael Kahn team-taught a Mathematics Practicum course while at St. Olaf. Kahn and Tommy Ratliff, familiar with the course from his time at St. Olaf, felt that such a course would provide an extraordinary applied consulting opportunity for our students. The course Kahn was familiar with was a one-month, interim course, but we envisioned a fuller experience for our students over the course of an entire semester. Starting such an endeavor would require substantial resources and effort, including contacting potential clients, local travel to their office sites, meals for faculty with potential clients, meals for students and clients during the semester, computing needs on our end to ensure both privacy and redundancy of information, and a course release so that both faculty could fully participate.

Without having a successful model to point to, it was unclear to the institution that initiating such a program would be prudent. Funding from Teagle allowed us to offer Math 285 “Mathematical and Statistical Consulting” in Spring 2007, and as will be documented in this section, the course was an enormous success for the students, as well as for the clients. Now that our campus recognizes both the value and feasibility of providing a real-world applied experience for students of Mathematics, Computer Science, and Statistics, this course will continue to be offered yearly. Further, Teagle funding provided an opportunity for travel to MathFest, the summer meetings of the Mathematical Association of America, in San Jose, California, where Wheaton students presented their results and Ratliff presented how we offered this course and how it might well be replicated at similar, small institutions where resources are restricted.

Recruiting Potential Clients
Since the focus was on the educational experience for our students, we did not promise to solve the clients’ problems necessarily, or completely. Thus, the problems could not be mission critical to the client. A great deal of the work put in by the professors was helping potential clients form open-ended research projects that were substantive, but manageable so that a successful outcome was possible. With these parameters, we do not
charge the clients a service-fee. We simply ask for a reasonable amount of their time working with the professors to formulate an appropriate problem, provide a working document(s) describing the background and statement of the problem(s) and gathering data where appropriate. In our case, as seen by the client testimonials, the students did, indeed, solve the problems more than satisfactorily and indicated new and further avenues for investigation. As an additional by-product of this work, we are building ties between the college and the local community.

Identifying clients with problems that match the goals of the course is difficult and takes patience. We had exploratory conversations with 8 to 10 firms and visited about 4 before we focused on problems from the two firms discussed below. Some of the firms were very interested, but did not have appropriate types of problems and another potential client could not get clearance from corporate headquarters regarding company time spent and confidentiality agreements. Since the clients initially view their participation as primarily community outreach, we must be sensitive to clients’ time commitment and special needs. For future implementations of this type of course at campuses like Wheaton, it should be noted that it is helpful to offer lunch meetings near the client’s office site during the exploratory conversations.

**Implementation in Spring 2007**

The course was team-taught by professors Kahn and Ratliff. There were two teams of four students each, consisting of 3 seniors, 4 juniors, and 1 sophomore. The teams worked independently from each other and met with their respective clients once per month at working lunches (meals and travel were grant-supported). These lunch meetings were invaluable as the questions raised by the students yielded insightful responses from the clients and the clients were excited and impressed by the partial results the students presented. It was a fun and productive way for the students getting to know the clients and for them getting to know the students.

By the end of the semester, each team produced substantial final products. The students gave formal, hour-long presentations to 20-25 professionals at the clients’ site with ample time for give-and-take with the audience. This is a key part of the learning process for the students since the professors were simply spectators at the back of the audience. It is the rare group of undergraduates who can put together a professional, informative, engaging group presentation, and we rehearse and practice these presentations for more than a week prior to the final presentation. The students really blossom over that time as they learn not just how to behave in front of a professional audience, but to think about what is necessary to move the story along in an honest, inviting, significant way. At the end of the presentation, the students provide the client with a copy of a white paper with results, as well as a disc with the presentation slides and any software/analysis files appropriate for the clients’ use.

The two teams of students were scheduled to meet with both faculty members once per week, and at least one scheduled meeting, typically more, of students. These meetings included faculty when they were asked to be part of the meeting, but often were without faculty. The students decided how to organize the tasks and responsibilities themselves.
There was a designated Team Leader and a Note Taker each week, with those roles being rotated among group members from week to week. Email reports from the Note Taker after each meeting (those scheduled with and without faculty) were sent to the entire group, including faculty, to practice good group communication, to provide structure and to document the work accomplished and the to-do list. These reports not only helped document the ideas that were bounced around, but helped clarify them, making it easy to put the good ideas into action and include them in the final report and presentation.

**Description of Projects**

One group of students worked on a project from the branch of the National Weather Service, located in Taunton, MA. The goal of the project was to build mathematical/statistical models to make long-range temperature and precipitation forecasts in New England. Hypotheses included a belief that four different oceanic and atmospheric indices will help predict temperature and precipitation. In particular, it was believed that “El Niño”, a measure of atmospheric data from a particular region in the South Pacific, is an especially important predictor of future temperature in New England. The students gathered data that included 30 years of monthly average temperatures and precipitation at six New England stations, and 30 years of monthly measures of the four oceanic and atmospheric indices. Students built both regression and time series models using these data to assess the predictive ability of these indices. Too simply stated, the conclusion was that there was no statistically significant relationship between indices and temperatures during non-winter months and that El Niño was never statistically significant.

The other group worked on a project from a branch of the Battelle Corporation in Duxbury, MA. The goal of this project was to assess thresholds (both point estimates of these thresholds and the variability in these estimates) used to close estuaries in Long Island to shellfishing. The data consisted of more than 15 years of various coliform measurements for 24 locations in Peconic Bay, Long Island, NY. The students spent a good deal of time combing through and cleaning up the data. They were then able to replicate results from a previous study using these data and went on to build confidence intervals for coliform thresholds using transformations from a lognormal distribution. The work indicated how much variability exists in typical measurements used for making decisions regarding the opening and closing of shellfishing areas, exposing some of the subtleties involved in evaluating contamination levels and the potential to affect policy for threshold for closure.

Please see attached letters praising the project and the students from the clients.

**Challenges and Future Modifications**

Running this course over an entire semester requires dealing with some challenges. There is the potential for student conflicts, both scheduling and personality, over the 3.5 months; the workload is heterogeneous over the semester, with an especially large amount of work at end of semester given students’ other course work, final exams, and job and graduate school applications for seniors. The non-traditional class structure requires faculty to give up most of the control they are used to having in a lecture-based course, but the rewards are enormous! It is truly wonderful to watch students meet and
overcome these challenges, accomplishing the clients’ goals, giving a very professional presentation and turning in a polished product.

There were a number of facets of the course that we would consider modifying for the future. Regarding the structure for interaction between teams, we would like each team to give updates to the other team at various points of the semester and for each team to help critique the other’s final presentations. We will use current students as resource for future students, we intend for each faculty member to take primary responsibility for logistics of one of the two projects. Finally, we hope to recruit non-math majors, even non-math faculty to help with this course, expanding its interdisciplinarity.

Long Term Effects at Wheaton and Dissemination
In the end we were very happy with this experience and very grateful to the Teagle Foundation for providing us with the funds to get this course up and running. It is an expensive course in faculty resources since it is team-taught to 8 students. Based on the extreme success this spring, the department is strongly committed to offering the consulting course every year; it is simply an invaluable resource for students.

Thanks to the grant funds, 6 students were able to attend MathFest, the summer meetings of the Mathematical Association of America, in San Jose, California, on August 3 – 5 and present their work. The students’ talks were both well-attended and well-received. One of the organizers of the Undergraduate Talks attended the session when our students spoke, and she told Professor Ratliff several times how impressed she was with all of the presentations. There were seventy-five (75) undergraduate talks at MathFest, and eight (8) awards given. Rachel Bayless, one of the Wheaton students in the consulting course, won one of these awards! The organizer told Professor Ratliff after the award presentations that the committee had a very hard time choosing among all of the Wheaton talks.

Further, Tommy Ratliff presented a talk “Mathematical and Statistical Consulting at Wheaton College” at MathFest in the session titled Student Research in Industrial Mathematics. Through this session, he made contacts with faculty at San Jose State, Towson University, and Harvey Mudd College who also offer industrial experiences for their students, although each of these programs have significant administrative support beyond the faculty who are teaching the course. He spoke with faculty from several smaller schools who were interested in implementing a program similar to the one from Wheaton since they felt that our “consulting” model was more feasible at their institutions.

We are very proud of this course and are also exploring appropriate journals for an article describing the Mathematical and Statistical Consulting course.

Selected Student Comments
Student 1
Learning in the consulting course was more of a discovery than any lecture course could be because we chose what we were learning, we asked the questions we needed
answered, and we found the answers to a previously unanswered questions. A much more personal attachment was made to work done for this class because it was all ours. This class shed light on new, more motivated ways of learning for me.

Student 2
Overall, the Consulting course was a rewarding experience and quite different from my other classes at Wheaton. I found it to be a nice change of pace from my other mathematics courses and was excited to work on a real problem for an actual company. I would definitely encourage other students to take this course. In many ways, I feel like I was exposed to the joys and tribulations of working as a consultant for a company. This is exactly what I had hoped to experience.

My main reason for taking the course was the culminating presentation. Initially, I was hesitant to take the course because of my fears associated with public speaking. However, it was this that actually pushed me to enroll. By the end of the semester I felt well prepared for the presentation and confident that our group would be successful. After it was done I felt an amazing sense of accomplishment.

Student 3
I have encouraged a few [students] already [to participate in a future Consulting course]. I think that, if anything, this course helps students develop a certain amount of professionalism and, in general, confidence. To be able to learn something and explain it to someone else in a professional setting is a very useful skill.

Student 4
The presentation was probably the most helpful part of the entire course. It is different to give small presentations in class than to give formal presentations. I learned about my weaknesses and will always consider them while preparing presentations in the future. Small tips like how to prepare effective PowerPoint’s (too many words) and to take a glass of water when I get up to speak (in an effort to slow down) make the world of a difference. Furthermore, with a bit of experience giving this type of presentation, when I have to do it again the nerves will be a bit more settled.

Working in a group is a skill I’m still working on. I’m very particular about how things are done and I’m trying to work on letting the little things go. I often want to do all the work myself, so that I’m sure everything is done and meets my personal expectations. But, this is not practical nor is it healthy. After working in a group for the entire semester, I became less particular and began trusting more in my fellow group members.

Faculty Collaborations and Feedback for Advancing QA in the Curriculum
The Math/CS department balanced an interesting agenda in meeting with faculty and students in what we see as our client departments over the academic year. It was our desire to engage them in a dialogue, learn what they think we do well, and find out what their “wish list” for us was. At the same time, we wanted to avoid these meetings turning into vent sessions where Math/CS was seen as a problem that needed to be addressed. Fortunately, all the people we interacted with, including students, understood the goal
was to work together as a team and get at the roots of ways that our pedagogies intersect to facilitate learning more profitably for all involved.

A common theme that emerged revolved around the software that the mathematicians use in teaching Statistics, Calculus, and Linear Algebra. We were surprised and disappointed to learn that this software was not employed in problem-solving in our client departments. More discussion helped illuminate that part of the problem is that we use powerful software that is also sound for our pedagogical purposes, meaning it helps illustrate the process of doing math. Client departments tend to use software that hides the math by having it reside embedded in pre-programmed commands.

This different orientation points to the gulf between math and other disciplines: Learning math and doing math tend to be different from applying math as a tool in a discipline. Pursuing the metaphor, in our classes we try to open the toolbox for students, hand them tools, explain how they work, explain ways in which they are dangerous, explain the limitations of the tools, provide examples for students to use the tools in a variety of contexts, and then hope and expect that the knowledge will move with the students to their other classes. We know it is often the case with math problems that students have a hard time seeing that the different manifestations and variables use common operations for the solution. We have tried to demonstrate this universality of problem solving for students in their work in other courses, using the software we taught them. It opened up interesting discussions within the department about the best ways to help our students bridge the difference between different kinds of software, including trying out the software that our client departments use.

Another area requiring better coordination among departments is related to the timing of course offerings. The scheduling process needs to be streamlined in such a way to help students avoid scheduling conflicts and be able to take their pre-requisites at the right times in their trajectory through Wheaton.

Members of the Core Working Group met with a number of departments to elucidate how QA is perceived and find ways to better integrate the QA knowledge and skills into the discipline-specific work.

Chemistry Department—March 30, 2007

The main concern of the Chemistry Department—both faculty and students—is how to help students review and improve their algebra skills. We suggested working with Chemistry (and Physics, Biology, and Economics) to develop review modules, so that chemistry professors (and others) could require their students to successfully complete those modules relevant to their courses, possibly offering credit to their students for passing. We talked about what types of problems are most important. These include: 1) the distributive property, 2) finding common denominators, particularly when a variable is present in the denominator, 3) solving for a variable in a denominator, 4) and logarithmic properties. We also discussed the mechanics of creating and administering such modules, but reached no final decisions. Faculty also discussed the similarities and
differences in using Maple, MathCad or Mathematica relative to problem-solving in Chemistry.

Economics Department—April 10, 2007

Because QA courses are required for Economic majors and minors, there is already strong familiarity and good dialogue between the Math/CS and Economics faculty members. Most of the conversation focused on which math courses should be prerequisites for or linked with which economics courses. There is a desire to eliminate the Mathematical Economics course offered by the Economics department and encourage these students to take Math/CS courses. The Economics faculty endorses the algebra tutoring program.

Education—April 11, 2007

All early childhood education and elementary education minors are required to take a specific 3-credit course for licensure and this is Math 133: Concepts of Math. New registration procedures have been instituted to ensure that these students are not closed out of the course, which is popular and is open to all students. Related to this course, the MA Department of Education posed the possibility of requiring 9-credit hours of mathematics for licensure. After much discussion, it was decided that the best way to fulfill that requirement, should it take effect, was to add Math 141: Introductory Statistics as a requirement with no changes to the content of the course, and add Math 127: Colorful Math as a requirement but changing the content to feature more emphasis on geometry. This would place an enormous strain on education minors who already carry a heavy course load. We wrote a letter to the Department of Education expressing these views and suggesting that they reduce requirements in other areas. As it turns out, the Department of Education chose not to make any changes as yet. We attach the letter we wrote and note that Wheaton, along with Boston University and Fitchburg State College, were the only colleges to respond to the request for Public Comment on the new DOE Math Guidelines for Teacher Preparation.

(attached letter, as mentioned above)

To: George Sheehan  
From: Wheaton College Mathematics and Education Faculty  
Date: April 11, 2007  
RE: Response to Guidance for the Mathematics Preparation of Teachers at the Elementary Level  

Thank you for the opportunity to respond to the proposal. Fortunately, at Wheaton we work collaboratively as faculty across disciplines to support the preparation of our future elementary teachers. In fact, this year we are proud to note that two of our student teachers have been named Fulbright Scholars. Together, Mathematics and Education department faculty have generated our response.
We agree that elementary teachers need to have a broader and deeper knowledge of mathematics. We also agree that additional mathematics coursework would be beneficial. However, we are concerned that the current regulations regarding 36 hours of arts and science “course distribution” requirements already make it very difficult for our prospective teachers to graduate in 4 years. Merely adding more courses to this rigorous load would significantly impact the maintenance of 4 year initial licensure programs and possibly reduce the number of students interested in the elementary license. Even today, students who should have time to explore options once starting college must decide early on if they want to pursue the initial elementary license in order to complete it within 4 years.

Thus, we recommend that the number and array of course distribution requirements be revisited if the number of mathematics courses is to increase. For example, we have observed the heavy emphasis on “social studies” type requirements (U.S. history, world history, political science, etc.) with limited emphasis on mathematics. Therefore, we would recommend requiring a maximum of three mathematics courses given a comparable reduction in the number of course distribution requirements overall.

We also agree that the Education Department course offering regarding the teaching of mathematics to children is an essential complement to the courses offered in the Mathematics Department.

Thank you for your consideration of these recommendations. Please feel free to contact us for more detail.

Sincerely,

Rochelle Leibowitz, Ph.D., Mathematics, Professor of Mathematics
Harrison Straley IV, Ed.D., Mathematics, Quantitative Analysis Associate
Vicki Bartolini, Ph.D., Education, Associate Professor of Education

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Physics/Astronomy—February 28, 2007

Three Physics students reported that faculty and researchers who supervised their external internships were surprised that Wheaton students did not know and use MatLab. The students asked whether the Math faculty would consider using MatLab rather than Maple.

The Physics faculty will review the mathematics that they cover in their 200- and 300-level Physics courses (e.g., Classical Mechanics, E&M, Thermal, Mathematical Physics) and let the Mathematics faculty review if those topics are covered in Multi, Linear, DiffEQ, etc. The two departments, whenever possible, will discuss scheduling of the next year’s courses to achieve the best content balance as well as avoid time conflicts.
The Physics and Geology programs are considering how to become more “computational” and want their students to take Computer Science 115. Physics and Astronomy would like students to be able to “read” and understand differential equations qualitatively. The physics and geology faculty agreed to discuss how faculty from the Computer Science and Physics/Geology departments might team-teach a “Scientific Computing” course that focuses on introductory numerical analysis and modeling.

Faculty and External Lectures

We were fortunate to host several superb sessions that brought new focus to QA while creating new venues for interdepartmental activities. The intersections involved faculty and students in Sociology, Economics, Political Science, Art and Biology. We were pleased that some of the most effective and interesting speakers were suggested by faculty members in different fields. When faculty members were offered the chance to bring in an interesting speaker who might catalyze interest in QA in students and/or faculty, names bubbled up and bridges were built.

On April 10th, Arthur Ganson, a world-renowned sculptor whose work focuses on kinetics, delivered a lecture titled “Gestural Engineering: Mechanics, Sculpture and the Art of Breathing Life into the Inanimate.” Mr. Ganson was artist-in-residence at MIT where there is a permanent display of his work at the MIT Museum. He also has pieces on display all over the world. Mr. Ganson has been featured in the Smithsonian Magazine, The New York Times Magazine, and Forbes. The Smithsonian Magazine article ended with the poetic sentiment, “Any engineer can build a machine that waves. Arthur Ganson can build a machine that waves good-bye.” We brought him in to meet with two sculpture classes, give a public talk, and dine with art faculty and students.

For the sculpture classes, he brought in part of a work in progress: He constructs his own gears, ratchets, and connecting pieces and thus what he showed students at first looked little like art. But, when he assembled the pieces and provided motive and force, the piece began to precess, move about, gyrate and somehow evoke the dance of the cosmos. Understandably, the students gave him ‘artistic street credibility’ and opened up to discussions with him of their work, where they were heading, and what sorts of things his work inspired.

After his classroom visits, he went to the Physics Department to meet with the team of students who were building an homage to his “Machine With Concrete,” a meditation on exponential decay. He respectfully looked over their interpretation of gearing down a sequence of cams and talked about how they solved problems differently than he did. This meeting bridged Physics and Art, and all left elevated in spirit.

Ganson filled a lecture hall holding about 70 physicists, mathematicians, biologists, sculptors, and other artists. He opened his talk by relating his background in science; in particular, in high school, he described how he programmed computers via punch cards and talked of what it was to dream up an algorithm to solve a problem, and then grapple with programming it. The next thing he said electrified the audience. After a pause, he
looked out and said, “I’ve always thought of sculpture as solving programming problems in three dimensions.” This one idea managed to shape the rest of the talk and demonstration, in which he revealed how his poignant “gestural objects” were expressions of math ideas, his solutions of self-imposed engineering and physics problems, and attempts to capture poetry with machines. The scientists got art in a new way, and the artists surely got QA and science in a new way. It was a revelation.

Dinner with Ganson was mostly students and a few faculty. Consequently, the students had much latitude to talk with Ganson and pursue the ideas that had cropped up in the afternoon visits and in his lecture.

On February 26th, Dr. Odis Johnson, Jr. presented a lecture titled “The Synthesis of Quantitative Information and Public Policy.” He explored three approaches to the synthesis of statistical information commonly referred to as “meta-analysis.” He pointed to how numbers inform policy debates and specifics of Headstart and school funding and neighborhood affluence as examples. He discussed vote counting methods, the synthesis of coefficients, and other research information with multilevel statistical methodology. Dr. Johnson received the National Academics Ford Foundation Dissertation Fellowship and the Spencer Postdoctoral Research Fellowship at the University of Chicago. He currently teaches at the University of Maryland and work as a political scientist affiliated with the Maryland Population Research Center where his focus is on bidirectional links between neighborhood characteristics, educational opportunities and social mobility. He is a member of the editorial board of The Urban Review.

Professor John Grady, Department of Sociology at Wheaton, presented a workshop on September 22 titled “Writing About Numbers: Why Panic When a Good Sentence Will Do?” He discussed basic quantitative reasoning as a way of telling stories about pictures. He asked participants to consider “narrative” as a means of interpreting evidence—in this case, data. He looked at some visual displays of information and then practiced interpreting those displays by writing about them in meaningful direct ways.

Cayla Kuhs, Adam Villa, and Erin Savolainen are three recent graduates of Wheaton’s Math/CS program who went on to graduate school in interesting QA-related fields. Kuhs is currently studying mathematical ecology, Villa is pursuing computer science, and Savolainen took a Masters in education and is teaching.

We invited Cayla Kuhs in as part of a joint venture with Biology to discuss how to use math--graph theory, probability, statistics, and algebraic geometry—as applied to biology in general, and ecology in particular. She also shared her experiences about attending grad school.

Bob Devany, Boston University, is a world-famous mathematician who works in the areas of chaos and fractals, and complex analysis. He proposed the most commonly accepted definition of a chaotic system and has produced many seminal papers. He incisively uses computers to generate ideas that he later shapes into theorems. In addition,
and what made him particularly attractive to us, he is renowned as an expositor and his quietly inspirational ways.

He lectured in a Calculus II class where he expanded on some of the ideas of the course, and showed how they lead to cutting-edge research concerns. He also presented a lecture—and filled Wheaton’s largest lecture hall—during which time he took aspects of his research and posed them in a way that students who are not inclined towards math and science might gain a sense of mathematics as an endeavor of ideas, rather than simply calculations. Although we weren’t able to survey the audience directly, judging by the lucidity of the questions and the general tenor, and by a random sample of post-talk informal interviews, the students came to appreciate that the pursuit of math is a human experience, that it can be a form of entertainment. There was a definite attitude shift, although of course it is impossible to say with any confidence whether or not the shift will persist into the future for the students.

Dr. Bernard Moses is Distinguished Professor of Business & Professional Studies at Voorhees College, a historically black college in South Carolina. He served in the Marine Corps and in law enforcement and taught at Shaw University, Mount Olive College, Cape Fear Community College before joining the faculty at Voorhees. We invited Dr. Moses to talk with sociology classes about his work, how he involves students in sociological research, how they code their results, and, similar to Dr. Johnson, how the numeric output of an academic can affect policy decisions regarding funding at the state level. Moreover, it was felt that as an African-American with a non-traditional educational background, he could serve as a role model, particularly with POSSE students. His class talks went well; the faculty and students uniformly were moved both by the content of his research and the QA means he used to capture it and communicate it. He helped lead the discussions and dialogue with POSSE students regarding QA. He was helpful, productive, and inspirational. He talked at length with several students who were concerned about adjusting to the academic culture of a predominantly white liberal arts college.

Erik Olin Wright, Professor of Sociology at the University of Wisconsin, was invited at the behest of the sociologists mainly to hold a symposium with the faculty and invigorate a discussion about the uses of QA in research. His work has led him in numerous directions; in particular, is that he tries to quantify class differences from a Marxist perspective. He led discussions with faculty at a dinner and breakfast, and gave a talk on the prospects of democracy stepping towards a Scandanavian form of socialism. Critical to the latter were the data he presented showing how various countries transform over time, particularly in regards to how immigrant populations can change attitudes. The talk may have been over the heads of many of the 70 students who were present, but the faculty found his work more convincing. Even more importantly, it helped them think about the ways in which QA can crop up first in their personal research and then subsequently in their classes.

Steve Rose, who was Undersecretary at the Department of Labor during Bill Clinton’s presidency, was invited by the Economics Department. The goals for his visit were to
strengthen ties between Economics, Sociology, and Political Science, under the unifying umbrella of QA. He gave a lunch talk to eleven faculty from a variety of departments—all of the above, plus Philosophy and others—in which he outlined his current research topic: The failure of the Democratic party to build a majority coalition due to fear-mongering about prosperity and misuse of data to present a false picture of gloom. His talk provoked quite a bit of discussion, and his performance and use of the data was magisterial.

Late that afternoon, he gave a modified version to about fifty students, again cutting across departments, and again provoking the students to grapple with his thesis, and try to contradict him. It became clear to most of them that there are a number of different ways to interpret a given data set, but certain kinds of judicious readings are more appropriate and justifiable and, ultimately, more plausible than others. This is a critical lesson to learn and one that we grapple with across all departments; indeed, it is one of the cornerstones of liberal education.

Dorothea Rockburne is another world-renowned artist; in contrast with Ganson, she works in two-dimensional media (Evidence of her eminence: A piece of hers is currently hanging in the MOMA in the 20th century drawing exhibit.). We teamed up with the Art Department—their motivation was simply that she is a pre-eminent female artist who has moved within a number of late-20th century artistic trends without ever devolving into derivative works. For us, the motivation was equally simple, and is based on her education at the Black Mountain College in North Carolina. During its brief, but telling, existence, Black Mountain College embodied a unique approach to learning that, in some measure, most liberal arts colleges seek to recapture. The professors at Black Mountain College were highly respected practitioners in their fields, classes were small, and the faculty tried to constantly spur each other to new heights by sharing ideas, methodologies, and research interests.

Early on, as she often said in her interviews, she expressed her fear of numbers, geometry, and logic to the resident mathematician, Max Dehn. Max Dehn was a close friend of Einstein, and he made profound contributions to a number of areas of mathematics, perhaps most tellingly in three-dimensional topology. When she revealed her discomfort with mathematics to Dehn, he reassured her that she could learn it, and took her on morning nature walks during which he would exhibit to her the ways that mathematics emerges from the world and can be decoded in nature.

We arranged for Rockburne to give a talk on aspects of her art and its development through the years, then, the next day, to meet with students and talk about their work, and then participate in an Art/Math (especially Max Dehn) Summit in front of students and faculty. Similar to Ganson, she lectured to a hall filled with students and faculty from departments across divisions. She talked about the influence of higher geometry on her predecessors’ works and on hers. She showed how one might trace an art history from some of her favorite epochs and artists through the early 20th century movements to her work. She talked at length about how she strove to assimilate current mathematical theories by ceaselessly thinking about them, trying to interpret them in an ever-refined
series of sketches and pre-visualizations, culminating in her personal transfiguration of the math idea into a two-dimensional work of art. It was sublime.

In the last forum, the Summit, mathematicians co-presented with Rockburne to a seminar room full of art students and interested faculty. We opened by giving a bit of background on some of Dehn’s more famous results, which is an exercise that we excel in at Wheaton: Taking graduate level concepts and casting them in a form that a curious undergraduate can understand. In deference to another one of her mathematical loves, we wove in some ideas relating to modular forms and Freeman Dyson’s CRANK.

She jumped in early and often and talked about how she has been working to understand the recently-solved Poincaré Conjecture, (and thus) three-spheres, homeomorphisms and homotopies. (The students were simultaneously numbed and dazzled. An artist curious about cutting-edge mathematics?) This led to a significant discussion about ways of thinking of objects that “live” in four dimensions and higher, and then cosmology by way of regarding the possibility for our universe to have a finite volume (which is more intuitive than an infinite space) that also has no boundary edges (because we can’t conceive of what would be beyond the edge of the universe).

Throughout this conversation, Rockburne added the tidbits that connected with her artistic interpretations of these fundamental topological ideas, but more importantly for the art students and faculty present, her bubbling enthusiasm made for an infectious “Math is Great!” atmosphere.

For the final part of the presentation, she talked about two works in progress. The first regards her sense of Poincaré and after a last-second push to finish it this summer, is currently at the Morgan Library. The second is a commission for a fresco in honor of Colin Powell at the US embassy in Jamaica. Here, she’s thinking about night skies seen from two different hemispheres at the same moment. The mathematicians began to speculate aloud on how math and science might approach the same topics.

Again, in front of literally gaping-mouthed students, Rockburne and the mathematicians began batting ideas around, and it was memorable for them to see a collaborative artistic exercise between mathematicians and an established artist.

Indeed, Rockburne was so impressed that she invited Bloch to come to New York to help her collaborate, in particular, on the Poincaré piece, for which she was feeling some artistic angst. She also wanted to follow up on particulars of the piece honoring Colin Powell; among other things, we connected her with Wheaton’s astronomer, Tim Barker.

Finally, due to the fact that Bloch understood the math and the art of what she was trying to accomplish, she invited Bloch to participate in a two-way interview with the Brooklyn Rail, a prestigious New York art magazine.
In part due to the potential collaboration with Barker, and due to the fact that the curator of our gallery made a connection with Rockburne, we will likely have a show of her astronomy drawings in the next few years at Wheaton’s gallery.

**Events, Displays, and Activities**

Spring 2006: Professor Tommy Ratliff took a group of six seniors to the Hudson River Valley Undergraduate Mathematics Conference, which draws over 400 students each year, making it the largest conference in the nation for undergraduate mathematics students. Five of the students presented talks based on their work in the Math Senior Seminar. The presentations were uniformly well-received and initiated questions and discussion from the audience. Gaining exposure, and contributing, to a vibrant, exciting mathematical environment with their peers from across New England and New York was one of the highlights of the students’ capstone experience in their major.

Met with Ioannis Miaoulis, Director of Boston’s Museum of Science to discuss conceptualizing displays and how to produce an engaging exhibit. We enjoyed wide-ranging conversations on audience dynamics, accessibility, placement, and “chunking” of ideas in the wall labels communicating the display’s message.

Purchased bronze sculpture of Alexander’s Horned Sphere, which is a very tactile counter-example to a famous conjecture from the early part of the 20th century. The conjecture noted that every circle (allowing for self-intersections) drawn on a sphere could be deformed within the surface of the sphere and shrunk down to a point. (This can’t be done, for example, on a torus, where a circle that goes around and through the hole in the center of the torus can’t be contracted to a point in the surface). The conjecture then notes that the space surrounding a sphere has this property, too: Any circle drawn in the 3-dimensional space around the sphere can easily be moved to avoid the sphere and then be contracted to a point. The conjecture (finally) says that if the sphere is distorted in 3-d space that this property is unchanged: Any circle in the space outside of the distorted sphere can still be contracted to a point. A mathematician would say that it seemed intuitively obvious. Alexander sought to prove the conjecture, and, in fact, published several false proofs. He kept publishing corrections and counter-examples until he decisively showed that the conjecture was false. The Alexander horned sphere is created by pulling out horns from the sphere and entwining them ever closer without ever actually touching (which would be an invalid deformation) and continuing this process infinitely and infinitesimally. This creates an “almost-torus” which prevents the circle in space from contracting to a point.

Block met with the Director of the Acton Discovery Museum about the creation of displays sustainable under the duress of constant use by kids and he solicited information about respected creators of exhibits, including Paul Orselli. Bloch followed up with Mr. Orselli, who is currently constructing the last lobby display, the Tube of Mortality. The ToM uses beads to graphically demonstrate the statistics of how Americans die. In short, it is a plexiglass tube that rotates like a roll of paper towels. It is filled with approximately one million and one beads that symbolize by number some of the ways that Americans...
died in 2002 (data obtained from the Center for Disease Control in Atlanta). The one distinctive bead represents the spinner of the tube, while there are 12 colors for all the other beads, each representing a select cause of mortality. For example, each red bead represents an American who died of AIDS and each pink one, a victim of Breast Cancer. With this exhibit, we hope to especially connect with people who prefer to see a concrete connection to their own lives. Some of the statistics are sobering: Despite the fact that AIDS awareness is very high, over 30 times as many people die of lung cancer, 5 times as many from suicide, 3 times as many from gun shots, etc. Scheduled completion and installation of the tube: late October.

ASSESSING AND EVALUATING CHANGES IN QA TEACHING AND LEARNING AT WHEATON COLLEGE

During faculty discussion leading up to the adoption of the new curriculum in 2001, it was argued uncontentiously that some sense of numeracy is an important part of a liberal arts education. In part, we sought to create coursework that would take abstract entities called “numbers” and successfully contextualize them in classes and in research papers that conveyed “What to numbers mean?” “How can we make sense of them?”, and “How can they help us in our various quests to understand the human condition?” How a sense of numeracy might be taught at the college level was, of course, yet to be determined. Though a mathematics requirement would fulfill some sense of numeracy, the desire seemed broader than “just mathematics” and the hope was that more courses across campus would satisfy the requirement; we would have a sort of “QA across the curriculum.” The faculty ultimately adopted guidelines that allowed courses that predominantly teach and make use of skills in any, or all, of the areas of logic, abstraction mathematical structures, statistics/data analysis or geometry/spatial concepts to be designated as QA courses.

To frame the evaluation of the QA component of the Wheaton curriculum, we gathered and analyzed data regarding enrollments in QA and formerly Math Logic (ML) courses by graduates from the years 2002 through 2007. Graduates from ’02 and ’03 used the previous ML requirement, while the graduates from ’07 are the first to truly use the QA requirement as part of the new curriculum. Graduates from ’04, ’05 and ’06 used the previous ML requirement, but course offerings available to those students were a mixture of previous ML offerings and the new QA offerings.

The most commonly subscribed QA courses over the last five graduating classes include Introductory Statistics, Calc I (or Calc I with Economic Applications), Logic, Concepts of Math, Mathematical Thought, The Universal Machine, Analyzing Social Trends, and Programming Fundamentals. Among all graduates between ’02 and ’05, these courses accounted for between 75% and 80% of all QA courses taken. For ’06 these courses accounted for 67% of all QA courses and for ’07 graduates, 71%.

Currently the majors at Wheaton that require QA courses are as follows: Biochemistry, Biology, Chemistry, Computer Science, Economics, Environmental Science, Mathematics, Physics, Psychobiology, Psychology, and Sociology. For those graduates
who had a major or minor that did not require a QA course (henceforth designated non-QA-req’d major/minor) the drop in the number of graduates was even greater. Among all QA courses taken by Non-QA-req’d major/minor graduates in ’02 and ’03, 86% and 88%, respectively, were from the commonly subscribed list of courses listed in the preceding paragraph. That percentage drops from ’04 to ’06 (81%, 78% and 77%, respectively,) with ’07 having only 74% of all QA courses taken by Non-QA-req’d major/minor graduates coming from this list of courses. The variation in QA courses taken among non-QA-req’d major/minor graduates in ‘07 is much greater than in the previous years. ’07 graduates were more likely to take courses such as Computing for Poets, Foundations of Computing Theory, The Edge of Reason, Colorful Math and Advertising Math, or Euclid (’06, in Classics) as a QA course.

The number of graduates taking Logic, Concepts of Math and The Universal Machine has remained relatively stable across ’02 to ’07. However, among non-QA-req’d major/minor graduates, there has been an increase in the percentage who take Analyzing Social Trends or Math in Art as a QA course. Among QA-req’d major/minor graduates there is still an increase in the percentage of students who take Analyzing Social Trends, but there is a steep decline in the percentage of QA-req’d students taking The Universal machine (was between 4% and 7% from ’02 to ’05, while only 1% in both ’06 and ’07).

Among all graduates, the number of QA courses per student remained essentially the same across the six years at between 1.5 and 1.7 QA courses per graduate. Among non-QA-req’d major/minor graduates there was a steady, though slight, increase from 1.1 QA courses/graduate in ’02 to 1.3 in ’07. On the other hand, among the QA-req’d major/minor graduates, the ratio remained steady across the six years at approximately 2 QA courses per graduate.

These data trends illuminate the trend that students are steadily enrolling in a broader spectrum of QA courses over the last six years as the faculty has developed a wider array of QA courses for students to take in response to the objectives set forth in the new curriculum.

There are also qualitative data to consider regarding the QA requirement. Brett Consulting was asked to run a series of focus groups for students and faculty discussing issues surrounding QA. Also, Bill Bloch and Michael Kahn met with different groups of students, including some closely connected with the Multicultural Center and those involved with the POSSE program, to discuss their perspectives on QA, and Wheaton more generally. In all of these venues, the overwhelming sentiment expressed by the students who were dissatisfied with their QA experience at Wheaton is that they felt they were in the wrong QA class. Worse, many of them found later that the QA class they took first (because they were advised to get QA “out of the way”) was different than the one needed for their major. It is in no way a bad thing for a student to take more than one QA course. On the other hand, to the extent that the students feel coerced into these courses for which there may be a good deal of anxiety anyway, simply perpetuates the bad press for “math.” On the other hand, a number of these students enjoyed the QA courses, happy to have taken both. In the end, the signal that we heard from the students is that advising surrounding QA must be improved. In particular, advisors and preceptors
must hear the message that there is no reason for any student to take QA right away, especially to “get it out of the way.” Depending on the major(s) a student is considering, they may be better suited to taking their QA course during their first two years, while others might wait until later.

Other changes in QA since the new Wheaton curriculum was implemented include hiring QA Associates and revamping the tutoring process, both of which appear to have greatly added value to the campus. In our discussions with students we heard many times how wonderful the QA Associates have been both within and outside of the classroom. Starting in the spring of ’04, Wheaton went from a model in which advising paired a tutor with a tutee for one-on-one sessions. Now there is a less formal, yet more effective structure where students may drop in at the QA Resource Center for intensive sessions when it works best into their schedules and frame of mind. Students report that they are receiving excellent help from the QA tutors. As with any such enterprise, there are issues that have been, and will need to be worked through. Some are personnel issues such as making sure tutors show up when and where they are supposed to, or getting other tutor’s to cover for them if they cannot make their scheduled time in order to have sufficient numbers of tutors to meet demand. Other issues have to do with carrying out their responsibilities, things such as making sure tutors keep up with the syllabi and material for the course, especially for courses with multiple sections and multiple instructors, and maintaining regular contact with the instructor. Overall, students are getting better help than they used to get and many of them meet and work together, collaboratively, more than they did in the old “one-on-one” model. Finally, this coming year (’07-’08), in response to discussions with faculty from other departments, we will have a tutor responsible for helping with college-algebra skills for students across campus. Students who are working in a chemistry lab or an astronomy class who need help with more common algebra skills will be able to meet with a tutor to work on problems and find resources for brushing up on these skills.

The current Advising system has been criticized for its impact on effectively elevating QA in the curriculum at Wheaton. Specific problems include the lack of preparation by advisors and preceptors to become familiar with the variety of QA course offerings and the kinds of schedules that make sense for taking QA courses. Efforts will be made to work with advisors, preceptors, and faculty in the first year seminars to better acquaint them with the variety, types and contexts of various QA courses.

**External Evaluation of QA in the Curriculum**

The Working Group engaged Brett Consulting Group to conduct two focus groups for students and two focus groups for faculty during April and May, 2007.

**Student Feedback**

The student sessions included individuals from all four years and a range of majors across humanities, social sciences and the natural sciences. The discussions may be summarized to include to following key ideas and several verbatims are included as well:

*Students understand the purpose of the QA requirement and see value in it because it expands one’s horizons and helps focus one’s interests.*
“I chose a liberal arts college because I would get a good background in a wide range of courses. I’m glad there is a requirement. I don’t really like math, and I wouldn’t have taken it. You can pick up a Time Magazine and there are statistics all over it. It is a true part of liberal arts education to be able to get that.”

“[The requirement] promotes the idea of a liberal arts education. You take a course in an area you would not have otherwise pursued, and you might actually like it and want to study it more.”

“The QA requirement gets students to do things out of their element and explore and do something they wouldn’t normally do.”

Several students mentioned that QA is broadly applicable, and that having taken QA courses contributed to a deeper understanding of content covered in non-QA coursework. One student felt that taking Statistics was necessary to learn about the manipulation of variables, which is relevant to many fields of study.

Everyone agreed that the way they learn in QA courses differs from how non-mathematical content is learned. Most students went into their QA courses thinking they would not do well because of this. Some feel QA courses are perceived as more difficult than most other courses; hence they require more work.

“I’m used to analyzing other people’s opinions and using my own opinion, I love writing papers, but I can’t do the ‘numbers thing.’ If you don’t have 76.342 as your answer, you’re wrong. It’s completely different.”

“I didn’t think I could do really well in Statistics. I watched others struggle with it, and I needed to spend a lot of time with my tutor and was afraid that my other grades would suffer. It was not a positive experience for me.”

“I never had to use a tutor as much as I did in my QA course.”

Most participants did not associate mathematics with creativity.

Six students felt that QA courses were not creative at Wheaton and attributed this to the focus on algorithms. These students contrasted their Wheaton experience with their high school math experience, in which many used “real world situations that made stats fun.” These students tended to steer away from Statistics at Wheaton because they were influenced by “so many people who hated it.”

A minority of students felt differently; that math involves creativity, especially at the higher levels.

“Lower levels of math have more constraints; math gets more creative as you learn more.”
“I like to figure things out, look at things in different ways. Math is like a puzzle.”

All students agreed that the level of creativity in the class was also contingent on who was teaching. Students raved about specific professors, and commented that students need to seek out professors who are a good fit with their individual learning style.

**Faculty Feedback**

Faculty members from the Humanities, Social Sciences and Natural Sciences Divisions participated in two sessions to evaluate perceptions and specific coursework in QA at Wheaton. Many of the same themes emerged as those discussed by the students.

**QA is a vital part of a liberal arts education and students who value the QA requirement are able to conceptualize it and apply it to “real life.”** Hence, advisors should do more to emphasize the rationale behind the requirement.

“You cannot offer a liberal arts education without reading, math and science. Including QA speaks to the breadth of the program.”

“Employers are telling educators that they are turning out people with substandard computational skills. We need to include QA to educate literate citizens.”

“The purpose is about getting people exposed to numbers and manipulating numbers for all different kinds of problems. There are so many different ways to fulfill the requirement. Get them to understand that maybe it isn’t about numbers, but it’s about symbols, and manipulating them to come up with a result. Numbers are everywhere, you can’t avoid them, so we need to look at them in different places. And I think the best example of ‘Yeah I do use it’ is this math in art class. Where the students learn about perspective and things they’ve experimented with but they don’t really know there is some theoretical basis for them. And they say ‘I really see where I’m using math and I appreciate it more.”

“It’s about finding the place where the numbers are going to be meaningful to you in some way. It doesn’t have to be numbers, it can be shapes, maps and other kinds of symbols, but understanding that it’s a way of thinking about the world. And today, especially with questions about prices, percents, energy consumption, you have to be able to look at those numbers in order to be able to trust the media. Look at them, and know when to be skeptical.”

One important suggestion is that QA should be a focus of extra-curricular activities such as the Sustainability Committee. QA is necessary to answer questions such as “How can Wheaton make better environmental choices?” Focus on QA’s role in addressing social issues which students care deeply about.
There is a culture of negativity around QA at Wheaton; participants lamented the presence of this prejudice and the fact that “nothing to do with QA could ever be perceived as remotely interesting or accessible.” Participants shared the perception that advisors steer students away from taking science and math courses.

Because QA courses are perceived as “more difficult” than courses in the Social Sciences or Humanities, advisors dissuade their students from enrolling in these courses. They were hugely disturbed by the implications of this, for students, faculty, and the Wheaton campus culture.

“We do ethical, cultural and ethnic dilemmas well here, but one thing I think we need to work on is adding more math and science to the typical liberal arts curriculum.”

“At Wheaton QA is taught as fact, as opposed to an approach; the mechanics precedes the description of the approach.”

“Math and science are perceived as difficult, and therefore undesirable.”

All participants believed that QA is relevant to every content area, and that to the best of their ability, many faculty attempt to infuse QA into their course material. However, some acknowledged that infusing QA taps into their own QA-related insecurities.

“In 20th Century History, we looked at the different wars and the numbers of deaths in each. I pointed out that although the number of deaths was larger in more recent wars, the population was larger as well, and you needed to look at percentages. If I hadn’t raised this issue, students wouldn’t have thought of it.”

QA faculty members are highly respected on campus. However, some faculty feel as if they are not getting the support they need from QA faculty to effectively infuse QA into their coursework. Faculty would also like to connect their non-QA courses to QA courses but doing so would involve a significant degree of time and effort.

“I had asked if someone could come in and design the unit I wanted to present but they never followed through. I’m not getting the help I need to do this.”

“There’s supposed to be a team of QA people reaching out, but I don’t think it’s happening.”

**SUMMARY AND CONCLUSION**

The Working Group is grateful for the opportunity to focus on QA at Wheaton College as evidenced by the initiatives, discussions, events, speakers, and assessment as described above. We believe that the lessons learned have relevance to sustain efforts to further strengthen QA in the Wheaton Curriculum while these descriptions, specific feedback, and recommendations hold merit for considering how math and QA are used and abused.
at other liberal arts colleges with the hope that new programs, courses, and dialogue will occur on new platforms across liberal arts education. Ultimately, our goal in undertaking this work is summarized in our title for this White Paper, *Expanding Quantitative Analysis as a Framework for Interdisciplinary Learning and Applied Problem Solving*, and has been the driving force of our efforts during the past twenty months.

We appreciate the support from The Teagle Foundation to underwrite these efforts and look forward to feedback as our colleagues read the White Paper and relate their own experiences in the effort to address problems related to the erosion in math proficiency and to ignite the subject throughout all disciplines in liberal arts education.