WASC Senior College and University Commission

EDUCATIONAL PROGRAMS

Retreat on Core Competencies: Quantitative Reasoning and Assessment in Majors

October 2-3, 2014

Kellogg West Conference Center, Pomona, CA

Resource Binder

WASC Senior College and University Commission | EDUCATIONAL PROGRAMS

2014-2015

WASC Senior College and University Commission is pleased to announce its educational programs for 2014-15. They cover topics of vital interest to all institutions but particularly to those in the WSCUC region. They have been developed by national and regional experts and are offered as a service to member institutions and others who wish to learn about good practices applicable to all institutions. They are entirely optional, but our hope is that member institutions will find them helpful. WSCUC staff will be present to answer questions related specifically to accreditation expectations.

- **Assessment 101: The Assessment Cycle, Clear and Simple**
  October 1, 2014. Kellogg West, Pomona, CA
  November 12, 2014. Kellogg West, Pomona, CA
  May 18, 2015. Chaminade University, Honolulu, HI

- **Retreat on Core Competencies: Quantitative Reasoning and Assessment in Majors**
  October 2-3, 2014. Kellogg West, Pomona, CA

- **Retreat on Core Competencies: Critical Thinking and Information Literacy**
  October 16-17, 2014. Hilton Oakland Airport, Oakland, CA

- **Retreat on Core Competencies: Written and Oral Communications**
  November 13-14, 2014. Kellogg West, Pomona, CA

- **President/Trustee Retreats**
  December 4, 2014. San José State University, San José, CA
  December 5, 2014. Woodbury University, Burbank, CA

- **Workshop on the Meaning, Quality, and Integrity of Degrees**
  January 30, 2015. Woodbury University, Burbank, CA

- **Assessment 201: Advanced Topics in Assessment**
  February 6, 2015. Mills College, Oakland, CA

- **The Big Five: Addressing Core Competencies**
  May 19-20, 2015. Chaminade University, Honolulu, Hawai'i

For more information on these programs, visit www.wascsenior.org/seminars. For specific questions, contact Julie Kotovsky, Educational Events Manager, at jkotovsky@wascsenior.org

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Retreat on Core Competencies: Quantitative Reasoning and Assessment in Majors
SCHEDULE

<u>Thursday, October 2, 2014</u>

8:00 – 9:00 am **Arrival, check-in, registration** *Registration Desk*

9:00 – 9:15 **Welcome** [M. Maloney] *Mountain Vista*

9:15 – 10:00 **What Do You Need? How Will You Get It? Team Strategy Session** [M. Maloney] *Mountain Vista*

10:00 – 10:15 **Snack break** *Exhibit Lounge*

10:15 – 11:15 **Plenary: Look, It's Math, It's Statistics, It's History and Psychology! It's Quantitative Reasoning!** [S. Elrod] *Mountain Vista*

11:15 – 11:30 **Introduction of mentors** [M. Maloney, J. Lindholm, S. Elrod] *Mountain Vista*

Jennifer Lindholm *Mountain Vista*
Helen Chen *Mountain Vista*
Susan Elrod *Auditorium*
Bernie Madison *Auditorium*
Eric Gaze *Campus Vista*
Donna Sundre *Poly Vista*
Maureen Maloney *Exhibit Lounge*

11:45 – 12:15 **Meet in mentor groups to schedule appointments** *Designated rooms & areas*

12:30 – 1:15 **Lunch in teams** *Dining Room*

1:30 – 2:30 **Breakouts**

1. **Developing and Evaluating QR Courses** [B. Madison] *Mountain Vista*
2. **QR across the Curriculum: From Creating Assignments to Measuring Outcomes** [E. Gaze] *Campus Vista*
3. **Why ePortfolios? Why Now? Documenting Learning with ePortfolios** [H. Chen] *Poly Vista*

2:45 – 3:55 **Topical Reflection Sessions: Mentors facilitate discussions based on their topics of expertise; participants are free to move in round-robin fashion through the sessions.**

Helen Chen (*Mountain Vista*): Using technology to support learning and assessment
Susan Elrod (*Auditorium*): Leading change
Eric Gaze *(Campus Vista)*: Managing faculty development and workload
Jennifer Lindholm (*Mountain Vista)*: Building a culture of assessment; capstones
Bernie Madison *(Auditorium)*: Using rubrics
Donna Sundre (*Poly Vista)*: Developing/using assessment instruments, approaches
Maureen Maloney *(Exhibit Lounge):* What does WASC really want?

2:45 – 3:15 **Each mentor hosts a discussion** *(see above for topic/room)*
3:25 – 3:55 **Each mentor hosts a discussion** *(see above for topic/room)*

4:00 – 6:00 **Work Session: Team Planning/ Appointments with Mentors** *Designated rooms & areas*

Three mentor slots:
4:00 – 4:40
4:45 – 5:25
5:30 – 6:10

6:15 **Dinner** *Dining Room*

Friday, October 3, 2014

7:30 – 8:30 **Breakfast** *Dining Room*

8:45 – 9:45 **Plenary: Developing a Campus Culture that Embraces Outcomes Assessment** [J. Lindholm] *Mountain Vista*

10:00 – 11:15 **Breakouts**

4. Student Learning Assessment and Academic Program Review [J. Lindholm] *Poly Vista*

5. Designing a Mature Quantitative Reasoning Assessment Plan for the Major [D. Sundre] *CampusVista*

6. A Framework for Leading Campus-Wide Change Initiatives [S. Elrod] *Mountain Vista*

7. Expectations for Student Performance at Graduation: What, Why, and How [H. Chen, M. Maloney] *Garden Vista*

11:15 **Snack Break – pick up and take a snack to your work session** *Exhibit Lounge*

11:15 - 12:45 **Work Session: Team planning/Appointments with Mentors** *Designated rooms & areas*
Two mentor slots:
11:15 – 11:55
12:00 – 12:40

12:45 – 1:30 **Lunch and team time or networking with other teams** *Dining Room*

1:30 – 2:30 **What Have We Learned? What Have We Accomplished? Round Table Discussion** [M. Maloney] *Mountain Vista*

2:30pm **Retreat ends**

*** Sessions Descriptions ***

Plenaries:

Look, It's Math, It's Statistics, It's History and Psychology! It's Quantitative Reasoning! [S. Elrod]
Quantitative reasoning (QR) isn't just math. It is a way of looking at the world "through mathematical eyes" and "thinking quantitatively about commonplace issues, and to approach complex problems with confidence in the value of careful reasoning" (MAA, 2013). This sounds simple enough; however, many colleges and universities struggle with how to define QR as a learning outcome, how to assess it, and

how to incorporate it into the curriculum. There are implications for student learning, program implementation, and especially faculty development – because if this requirement is to be met primarily across programs and disciplines (i.e., not just in a math course), faculty teaching those courses will need help with assignments and assessments that properly measure students' QR.

Developing a Campus Culture That Embraces Outcomes Assessment [J. Lindholm]
Our beliefs and assumptions about assessment programs and practices present one barrier to the effective use of assessment. However, an even bigger challenge is the cognitive shift that must take place, both within and across disciplines, in how we perceive assessment and how we respond to feedback. This session addresses issues that transcend institutional type or disciplinary context; the goal is to engage retreat attendees in considering how they can facilitate the long-term success of their assessment- and accreditation-related efforts within their own campus communities.

Breakouts (in the order in which they appear in program):

1. Developing and Evaluating QR Courses [B. Madison]
In the absence of widely accepted content for QR courses and recognizing the difficulty of measuring long term retention and transfer, how does one develop or evaluate QR courses? A research-based method, rooted in a decade of developing, teaching, and studying QR, courses will be presented and discussed. The ingredients of the method are widely applicable in undergraduate education. Ways to effectively assess student QR learning, although fraught with challenges, are beginning to emerge as more is learned about how students interact with the transformational learning that seems to be necessary.

2. QR Across the Curriculum: From Creating Assignments to Measuring Outcomes [E. Gaze]
This workshop will introduce participants to what is meant by quantitative reasoning (QR), articulating the distinction between QR and traditional mathematics instruction. This will lead into a discussion of ways to create authentic QR assignments for courses across the curriculum. These assignments will be grounded in the mantra "sophisticated reasoning using elementary mathematics versus elementary reasoning using sophisticated mathematics." In particular, mathematics for informed citizenship and personal decision-making will be explored. The session will end with a focus on assessment, including results from a National Science Foundation project of a QR instrument that has been piloted at institutions across the country.

3. Why ePortfolios? Why Now? Documenting Learning with ePorftfolios (H. Chen)
E-Portfolios are more than just a technology; they imply a process of planning, keeping track of, making sense of, and sharing evidence of learning and performance. This interactive session will introduce a framework for designing and implementing an ePortfolio approach to meet specific learning outcomes and objectives related to both majors and core competencies.

4. Student Learning Assessment and Academic Program Review [J. Lindholm]
A strong academic program review process can provide a cornerstone for establishing and sustaining an institutional culture that supports new forms of student learning assessment. This session offers approaches to linking assessment-related initiatives with the academic program review process, strategies for working with academic units to address assessment-oriented components within self-study reports, and considerations for establishing manageable expectations based on institutional context.

5. Designing a Mature Quantitative Reasoning Assessment Plan for the Major (D. Sundre)
This interactive session will guide participants through a design process featuring development of assessment tasks for majors. We want to build on goals and objectives that are to be met in particular classes and build across major requirements. The development of program determined assignments (PDAs) that are required for all sections of a course and build skills longitudinally represents a mature major curriculum and assessment design. This type of design ensures appropriate scaffolding with opportunity for students to practice and receive feedback on the objectives identified by the program. Participants will be invited to identify an important QR learning objective from their institution and to explore how it builds across courses. We want to identify the program logic that clearly exists across all curricula—but are seldom explicitly stated.

6. A Framework for Leading Campus-Wide Change Initiatives [S. Elrod]
Implementation of a new campus-wide requirement for quantitative reasoning or use of a common assessment method requires changing the current status quo in favor of the new program. In order to successfully navigate the planning, political and personnel issues involved in change projects, faculty leaders and administrators should consider how best to manage the process. The Keck/PKAL Scientific Framework for Strategic Change takes a scientific approach to facilitating change and offers leadership, planning, assessment, and tools

for developing a strategic plan for change, including evidence-based practices. The Framework also provides "readiness" tools for assessing the capacity for change in terms of faculty expertise, resources, and campus infrastructure. In this session, participants will learn about the Framework with case study examples from participating campuses. Participants will apply the framework to their campus initiative to develop a plan for creating a comprehensive change agenda for their institution.

7. Expectations for Student Performance at Graduation: What, Why, and How [H. Chen, M. Maloney]
WSCUC's 2013 Handbook of Accreditation calls on institutions to address students' performance in five core competencies: quantitative reasoning, along with writing, oral communication, critical thinking, and information literacy. Specifically, institutions are asked to set a standard of performance in each competency that they expect students to achieve at or near graduation; assess graduating students' performance; report how well students meet each standard; and present plans for improvement when needed. Ideally, the process of standard-setting involves some form of comparison, and the assessment includes some form of external validation. Learn more about why the 2013 Handbook includes these expectations, and join a conversation, as we all explore this new ground, about how they can best be met.

Kellogg West Conference Center & Hotel

MEETING/EVENTS ROOM FLOOR PLANS

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Mentor Biographies

WASC Retreat on Core Competencies:
Quantitative Reasoning and Assessment in Majors
Mentor Biographies

Helen Chen

Helen L. Chen is a research scientist in the Designing Education Lab in the Department of Mechanical Engineering and the Director of ePortfolio Initiatives in the Office of the Registrar at Stanford University. She earned her undergraduate degree from UCLA and her PhD in Communication with a minor in Psychology from Stanford University in 1998. Helen is a co-founder and co-facilitator of EPAC, a community of practice focusing on pedagogical and technological issues related to ePortfolios (http://epac.pbworks.com). She works closely with Association of American Colleges and Universities as a member of the Assessment Advisory Group for the Quality Collaboratives project and as a faculty member for the Institute on General Education and Assessment. Helen is also the Director of Research for the Association for Authentic, Experiential and Evidence-Based Learning (AAEEBL) and a senior scholar on LaGuardia Community College's FIPSE-funded Connect to Learning project. She and her colleagues Tracy Penny-Light and John Ittelson are the authors of Documenting Learning with ePortfolios: A Guide for College Instructors (2011, Wiley). Helen's current research interests are focused in three areas: persistence in engineering education; documenting innovations in teaching and learning in next generation learning spaces; and the use and applications of ePortfolio pedagogy and practices in general education, the disciplines, and co-curricular experiences.

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Susan Elrod

Susan Elrod is the Dean of the College of Science and Mathematics at Fresno State. She holds a Ph.D. in Genetics from the University of California-Davis and a B.S. in Biological Sciences from California State University-Chico. At Fresno State, she is PI of an WM Keck Foundation funded project that has developed a framework for strategic change in STEM (science, technology, engineering and mathematics) education and Fresno State's NSF-funded FLOCK project that aims to enhance faculty development and introductory course outcomes in biology, calculus, chemistry, and physics. She also participates as a co-PI on a new NSF-funded national project to form a network of biology faculty developers. Prior to joining Fresno State, she was the Executive Director of Project Kaleidoscope (PKAL) at the Association of American Colleges & Universities in Washington, D.C. In this position, she launched several multi-campus, national STEM education initiatives focused on interdisciplinary learning, sustainability, and transfer student success. She also expanded PKAL's national program of regional faculty development networks and enhanced PKAL's Summer Leadership Institute. From 1997 – 2012, Elrod was a professor of Biological Sciences at Cal Poly, San Luis Obispo where she taught extensively and conducted both scientific and educational research. Among her administrative accomplishments, Elrod led development of their WASC institutional proposal self-study themes, served as assistant chair of the Biological Sciences Department, associate dean in the College of Science and Mathematics, and as the director of the Center for Excellence in Science and Mathematics Education (CESaME). At CESaME she was responsible for the growth of the STAR STEM Teacher Researcher program, which is a summer research program for aspiring science and mathematics teachers. In addition, she has more than 10 years of experience leading faculty development programs, consultations with campuses and organizations regarding undergraduate STEM education reform, and was an American Council on Education (ACE) Fellow. She is a California native and enjoys spending time in the great outdoors.

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WASC Retreat on Core Competencies:
Quantitative Reasoning and Assessment in Majors
Mentor Biographies

Eric Gaze

Eric Gaze directs the Quantitative Reasoning (QR) program at Bowdoin College, he is a past chair of SIGMAA-QL (2010-12), a board member of the National Numeracy Network (NNN 2010-13), and NNN Vice-President (2012-13). He writes a column, Ratiocination, for the NNN website: http://serc.carleton.edu/nnn/columns.html . Eric has given talks and led workshops on the topics of QR Across the Curriculum, Creating a QR Entry Point Course, Writing with Numbers, QR Assessment, and Running a QR Program; and served on review teams of QR programs. Eric is the Principal Investigator for a NSF TUES Type I grant (2012-13), Quantitative Literacy and Reasoning Assessment (QLRA) DUE 1140562. This collaborative project builds on Bowdoin College's QR instrument which is used for advising purposes and is available to interested schools. Prior to coming to Bowdoin, Eric led the development of a Masters in Numeracy program for K-12 teachers at Alfred University as an Associate Professor of Mathematics and Education. He has given talks and led workshops on developing such an MS program and Infusing Numeracy Across the K-12 Curriculum.
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Jennifer A. Lindholm

Jennifer A. Lindholm is Special Assistant to the Dean and Vice Provost for Undergraduate Education at UCLA. In that capacity, she is responsible for coordinating campus initiatives that focus on enhancing undergraduate teaching and learning, addressing accreditation-related considerations, and facilitating student success. Her current efforts focus heavily on the Capstone Initiative, the Initiative to Evaluate the Effectiveness of Academic Programs for Undergraduate Students, and Pathways to Commencement. From 2001-2006, Jennifer served as Associate Director of the Cooperative Institutional Research Program at UCLA’s Higher Education Research Program and as Director of the institute’s Triennial National Faculty Survey. She also served as Visiting Professor of Higher Education and Organizational Change in UCLA’s Graduate School of Education and Information Studies. Jennifer was Director and Co-Investigator for the decade-long Spirituality in Higher Education project and co-author of Cultivating the Spirit: How College Can Enhance Students’ Inner Lives. Her second book in association with that project, The Quest for Meaning and Wholeness: Spiritual and Religious Connections in Faculty Members’ Lives will be published this January. Jennifer is also a featured contributor to Revisioning Mission: The Future of Catholic Higher Education. Her other research and writing focus on the structural and cultural dimensions of academic work; the career development, work experiences, and professional behavior of college and university faculty; issues related to institutional change; and undergraduate students’ personal development. Jennifer also works as a consultant to colleges and universities on topics related to her areas of research and practical expertise.
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Bernie L. Madison

Bernard Madison has more than 20 years of experience in assessment and 15 years of experience in research and teaching of quantitative literacy. He has several publications in each area and frequently consults and advises institutions of higher education on both. He is a professor of mathematics at the University of Arkansas, where he served 10 years as department chair and 10 years as dean of Arts and Sciences. He was the founding president of the National Numeracy Network, 2004-2008, and currently serves as Director of

Placement Testing for the Mathematical Association of America. Over the past 15 years he has directed NSF-funded projects in assessment, teacher education, quantitative literacy, and conceptually based placement testing. He currently co-directs an NSF mathematics and physics partnership that includes 42 school district partners. He earned his PHD at the University of Kentucky.
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Donna L. Sundre

Donna Sundre is Executive Director of the Center for Assessment and Research Studies (CARS; see http://www.jmu.edu/assessment) and Professor of Graduate Psychology at James Madison University (JMU). CARS is the largest higher education assessment center in the United States, and James Madison University has a strong and growing reputation for quality assessment practice. The university and the Center have been the recipient of nine national assessment awards (see http://www.jmu.edu/assessment/JMUAssess/awards/awards.htm). Donna has been an active assessment practitioner and consultant for 25 years working with assessment in general education, the majors and student affairs. Donna is a frequent invited speaker and workshop presenter in the areas of assessment practice, instrument development, validity, quantitative and scientific reasoning, and examinee motivation She has been a Principal Investigator (PI) for several grants associated with assessment practice (e.g., *Innovations in Technology, Assessment Fellowships, Senior STEM Scholars*) and instrument development (e.g., NSF grant on *Advancing Assessment of Quantitative (QR) and Scientific Reasoning (SR)*). She is very interested in engaging faculty and staff with assessment practice and scholarship. Her research and publication record are largely devoted to direct assessment of student learning, quantitative and scientific reasoning, validity issues, instrument development, and examinee motivation. She serves on several Assessment Advisory Councils and professional editorial boards. She earned her Ed.D. from the University of North Carolina-Greensboro in Educational Research and Measurement.
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Maureen A. Maloney (WASC representative)

Maureen A. Maloney Before joining WASC as a Vice President in October, 2012, Moe was a member of the Graduate Theological Union Student Affairs staff for 18 years. Moe served as the GTU Vice President for Student Affairs and Dean of Students from 2004 to 2012. Her previous roles at GTU included Assistant/Associate Dean for the Doctoral Program and Student Life Coordinator. Before joining the GTU staff, Moe was a research assistant with another consortium, the National Center for Research in Vocational Education. From 1984 through 1991, Moe was the head women's basketball coach for San Francisco State University. Moe has an Ed.D. from the University of California, Berkeley, a M.S. in Physical Education Administration from the University of Illinois, Chicago, and an undergraduate degree in Business Administration-Marketing from the University of Notre Dame. Her research interests are in higher education organizational theory, teaching and learning, student retention and graduation, and faculty development.
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Attendee Directory

WSCUC Quantitative Reasoning and Assessment in Majors
Attendee Directory
Pomona, CA   October 2-3, 2014

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Senior College and University Commission

EDUCATIONAL PROGRAMS

An Introduction to Quantitative Reasoning and Assessment in Majors

Susan Elrod

Jennifer Lindholm

Quantitative Reasoning: The Final Frontier of Core Competencies

Susan Elrod, Dean, College of Science and Mathematics, Fresno State

Introduction. Quantitative literacy. Quantitative reasoning. Quantitative fluency. These are phrases that are often used when discussing one of the key learning outcomes for higher education. Here are a few high-profile examples:

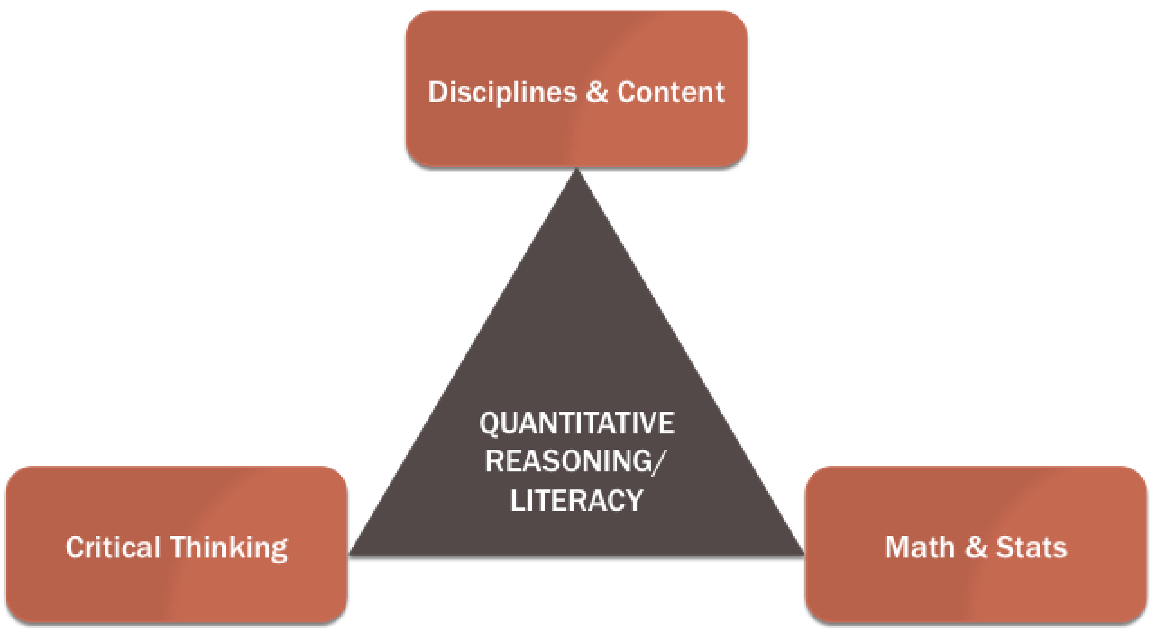
- The WASC Senior College and University Commission focuses on five core competencies -- writing, oral communication, quantitative reasoning, critical thinking, and information literacy – in its 2013 institutional review process.
- Quantitative reasoning is one of the LEAP (Liberal Education for America's Promise) Essential Learning Outcomes (or ELOs) developed by the Association of American Colleges & Universities (AAC&U) , along with inquiry and analysis, critical and creative thinking, written and oral communication, information literacy and teamwork and problem solving.
- The Lumina Foundation's Degree Qualifications Profile (DQP) calls this skill quantitative fluency and places it, like LEAP, among several important intellectual skills: analytic inquiry, information literacy, engaging diverse perspectives, and communication fluency.

The ability to think quantitatively clearly plays a central role in undergraduate education. But what do phrases like quantitative literacy, quantitative reasoning, or quantitative fluency really mean for student learning, the curriculum, program development, faculty development, or accreditation? How do we teach and measure it? Who is responsible for ensuring that students achieve this competency? This essay will define QR; discuss the role of QR in the undergraduate curriculum; present ways to define and assess QR outcomes; and finally suggest approaches to faculty development in QR. Throughout, I will provide examples of campus practice.

> Box 1. What is it?
>
> "Some call it **Numeracy**, an expression first used in the UK's 1959 "Crowther Report" to include secondary school students' ability to reason and solve sophisticated quantitative problems, their basic understanding of the scientific method, and their ability to communicate at a substantial level about quantitative issues in everyday life. Others call it **Quantitative Literacy (QL)**, and describe this comfort, competency, and "habit of mind" in working with numerical data as being as important in today's highly quantitative society as reading and writing were in previous generations. Still others refer to it as **Quantitative Reasoning (QR)**, emphasizing the higher-order reasoning and critical thinking skills needed to understand and to create sophisticated arguments supported by quantitative data."
>
> From the National Numeracy Network's website: http://serc.carleton.edu/nnn/index.html

Defining Quantitative Reasoning. Quantitative reasoning is the application of basic mathematics skills, such as algebra, to the analysis and interpretation of real world quantitative information in the context of a discipline to draw conclusions that are relevant to students in their daily lives. It is not just mathematics. Carleton College, for example, views QR as "the habit of mind to consider the power and limitations of quantitative evidence in the evaluation, construction, and communication of arguments in public, professional, and personal life." The term numeracy is also used in conjunction with these skills. A comprehensive statement of all three of these phrases is provided by the National Numeracy Network (NNN), an organization devoted to advancing quantitative reasoning learning, assessment, and program development in higher education (see Box 1). Ultimately, quantitative reasoning requires students to think critically and apply basic mathematics and statistics skills to interpret data, draw conclusions and/or solve problems within a disciplinary context (Figure 1). Indeed it requires the kind of mathematical and statistical skills generally learned by high school, so all college students should be able to achieve this outcome. It is a competency of integration and application, both of which are intellectual capacities up near the top of the cognitive skills taxonomy originally described by Bloom (1956). Thus, higher education faculty and administrators must address ways to provide students with learning opportunities to understand and practice this set of skills.

Figure 1. QR within the Undergraduate Curriculum



QR in the Curriculum. The development of intellectual skills is paramount for undergraduate students. AAC&U states that intellectual and practical skills should be "practiced extensively, across the curriculum, in the context of progressively more challenging problems, projects and standards for performance." The Degree Qualifications Profile provides another lens through which to view these skills, stating that "students hone and integrate" these skills across the curriculum when dealing with problems in their major field of study, but also with "broad, integrative problem-solving challenges." Thus QR appears to be much more than a general education learning outcome; it must be accomplished within the major, but also beyond it. Deborah Hughes-Hallett (2001) argues that QR must be taught in the context of the disciplines because a critical component is the ability to identify quantitative relationships in a range of contexts. She also argues that the very nature of QR is interdisciplinary because it involves contextual problem solving in real-world situations. Yet general education is where many campuses locate the teaching, learning, and assessment of core competencies like QR.

Examples of QR in everyday life abound and can be drawn upon to teach QR in the context of virtually any discipline. They can be found in areas such as health, economics, politics, science, engineering, social science, and even the arts. For example, virtually all parents face the vaccination question early in the life of their children. Parents might ask questions like, "What are the risks associated with vaccinating my child? What are the benefits?" In order to answer these questions, they must take into account quantitative information, such as disease occurrence rates in populations over time, or numbers of cases of complications with certain vaccine preparations. In today's information age, the Internet is the most readily available source of information, so students (and adults) must be able to discern reliable versus non-reliable sources. Returning to our vaccination example, there is rampant misinformation online about a connection between autism and vaccinations that must be recognized as such when parents formulate their decisions. Making judgments based on political polling data, understanding the national debt, interpreting nutrition facts, evaluating medical treatment or screening options, making investment decisions, and even purchasing decisions – these are all everyday challenges that require us to use quantitative reasoning skills.

Larger societal issues, such as climate change, also require the application of QR skills – and the closing of a widening gap between those who have these skills and those who do not. Issues like these are politically contentious, beyond the practical implications for everyday life and decision-making (should I buy a hybrid car? Should I buy carbon credits?). The "hockey stick" graph of rising CO_2 levels made worldwide news as politicians debated the science behind climate change, or global warming as it was known in the past decade. Jon D. Miller, a political scientist at University of Michigan who has been studying the civic scientific literacy of adults in the U.S.; in surveys that ask basic factual scientific questions, he finds that less than 30% are scientifically literate (Miller, 2010). Anthony Carnevale, Director of Research at the Center on Education and the Workforce at Georgetown University, argues that, "The remedy for the widening gulf between those who are literate in mathematics and science and those who are not is democratization – making mathematics and science more accessible and responsive…to the needs of all citizens" (in Steen, 2004, p.65). One way to achieve this may be through a more intensive focus on quantitative reasoning in college. There are implications for all levels of education, preschool through college, but our focus here is on the undergraduate curriculum.

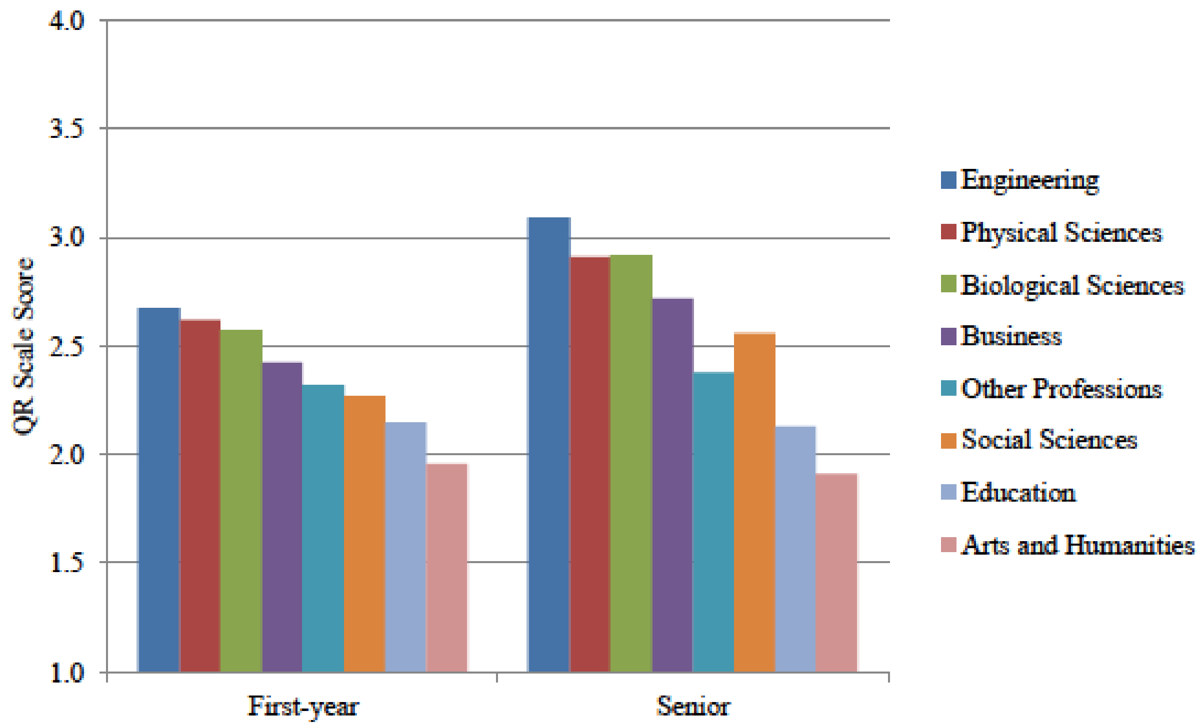
Challenges. A 2001 study by the Mathematical Association of America (MAA) summed up the challenges:

1. Most higher education students graduated without sufficient QR
2. Faculty in all disciplines needed professional development support to enhance QR in their courses
3. QR was not part of assessment activity
4. Education policy leaders were insufficiently aware of the increasing need for QR

While this study is more than a decade old, we may not be much further along today. QR is a complex outcome that requires immediate attention from faculty across the disciplines. Many institutions have embraced the core competencies of writing and communication, but far fewer attend to this equally critical outcome. In addition, there are special difficulties in reaching students. As Hughes-Hallett (2001) notes, they find it hard, especially when QR is taught in the context of the disciplines. She describes results from a study where students were given a quantitative problem to solve in the abstract and then in the context of a scientific problem. No scientific understanding was required to solve the problem, but students had trouble with the contextualized problem, in part because their perceptions of science or science phobia interfered.

One of the first decisions a campus must make when approaching QR learning is where in the curriculum students will be expected to gain these skills, and thus, where the faculty will both teach and measure it. A recent paper by Rocconi and colleagues (National Survey of Student Engagement, 2013) reports that students in STEM fields are more engaged in QR-related activities than those in non-STEM fields, with students in education and the humanities showing the least engagement (Figure 2). This may not be surprising, but it is illuminating, given that QR skills are important for *all* students. It is easy to assume that the responsibility for QR should rest with the mathematics portion of general education or mathematics faculty. But experts argue that QR goes beyond basic math skills, and that most math courses don't teach QR skills. There is a disciplinary context to the deep demonstration of QR skills by students that can most likely only be achieved by repeated exposure across the curriculum, along with culminating assessment in the major or a capstone experience. Faculty in mathematics departments may be best suited to take a leadership role in leading a campus-wide effort, but that effort must include faculty in other disciplines to have the broadest impact.

Figure 2. Average Frequency of QR Activities by Major and Class Level



Learning Outcomes for QR. As with any core competencies or higher-order intellectual skills, faculty and other educators should use "backward design" (Wiggins and McTighe, 1998) to define the desired outcomes and create appropriate assessments before designing learning experiences for students. The outcomes may be simple or complex, depending on the focus or the locus of QR in the curriculum, i.e., general education or the major or some other institution-level requirement. These outcomes may include the kinds of math skills required, the types of data students should be able to interpret, the methods to be used for problem-solving, the desired results of the application of these skills, and ability to clearly communicate findings. Other outcomes may include student attitudes toward accomplishing these kinds of tasks, or ability to make connections to learning in the major or across the curriculum. Steen (2004, p. 24) argues that there are three essential components to QR: 1) engagement with the real world (which may set it apart from traditional mathematics), 2) ability to apply quantitative thinking to unfamiliar contexts, and 3) adaptable reasoning, which is the ability to make judgments even in the "absence of sufficient information or in the face of inconsistent evidence." How often in the real world do we have all the information we need to make a solid judgment? Rarely. Thus, we should be preparing our students to grapple with this kind of uncertainty.

Several universities have already developed outcomes for QR. One example of a comprehensive set of outcomes for graduating seniors at the University of Virginia is shown in Box 2. These outcomes are quite extensive but traverse the terrain of basic understanding of quantitative information and processes, using QR methods, communicating quantitative information and evaluating quantitative information. Another example is the Degree Qualifications Profile, which defines quantitative fluency, in terms of both *what* students should be able to do and at what *level of skill* or performance.

At the associate level, the student

- Presents accurate calculations and symbolic operations, and explains how such calculations and operations are used in either his or her specific field of study or in interpreting social and economic trends.

At the bachelor's level, the student

- Translates verbal problems into mathematical algorithms and constructs valid mathematical arguments using the accepted symbolic system of mathematical reasoning.
- Constructs, as appropriate to his or her major field (or another field), accurate and relevant calculations, estimates, risk analyses or quantitative evaluations of public information and presents them in papers, projects or multi-media events.

At the master's level:

- Students who are not seeking a degree in a quantitatively based field employ and apply mathematical, formal logic and/or statistical tools to problems appropriate to their field in a project, paper or performance.
- Students seeking a degree in a quantitatively based or quantitatively relevant field articulate and/or undertake multiple appropriate applications of quantitative methods, concepts and theories within their field of study.

Some universities have set out a program for mathematics across the curriculum (MATC), much like the writing across the curriculum (WAC) movement that swept the nation a decade or more ago. Dartmouth College has an MATC program that has helped faculty from mathematics and the humanities create nine integrated courses. Other institutions have built quantitative reasoning centers that host programs – workshops, tutoring, peer mentoring, etc. – to help students achieve QR skills. For example, Bowdoin College has created a Quantitative Reasoning Program that provides advising, study groups, tutoring and supplemental instruction in support of QR learning goals. The college is also developing a test for use in academic advising that will measure incoming students' QR skill levels. This test analyzes the following areas: Computation and Estimation, Probability and Statistics, Graphical Analysis and Common Functions, and Logic/Reasoning.

Box 2. University of Virginia Quantitative Reasoning Outcomes

A graduating fourth-year undergraduate at the University of Virginia will be able to:

(1) Interpret mathematical models such as formulas, graphs, tables, and schematics, and draw inferences from them.
(2) Communicate mathematical information symbolically, visually, numerically, and verbally.
(3) Use arithmetical, algebraic, and geometric methods to solve problems.
(4) Estimate and check answers to mathematical problems in order to determine reasonableness.
(5) Solve word problems using quantitative techniques and interpret the results.
(6) Apply mathematical/statistical techniques and logical reasoning to produce predictions, identify optima, and make inferences based on a given set of data or quantitative information.
(7) Judge the soundness and accuracy of conclusions derived from quantitative information, recognizing that mathematical and statistical methods have limits and discriminating between association and causation.
(8) Solve multi-step problems.
(9) Apply statistics to evaluate claims and current literature.
(10) Demonstrate an understanding of the fundamental issues of statistical inference, including measurement and sampling.

Assessment. Many different approaches to assessing QR have been developed, ranging from direct to indirect measures of learning. Available tools include ready-to-use instruments and rubrics as well as survey and interview questions that assess attitudes toward mathematics in real world contexts. Examples are available on the national organizations' websites described in the next section, but I will describe three specific tools below.

The Center for Assessment and Research Studies (CARS) at James Madison University has developed the Quantitative Reasoning Test (Sundre, 2008). This instrument has been administered at over 50 universities to more than 20,000 students. It is a 25-minute multiple-choice exam that focuses on two key outcomes. These are ability of students to:

- use graphical, symbolic, and numerical methods to analyze, organize and interpret natural phenomenon; and
- discriminate between association and causation, and identify the types of evidence used to establish causation.

AAC&U's VALUE (Valid Assessment of Learning in Undergraduate Education) project has published a rubric for assessing quantitative literacy with six criteria: interpretation, representation, calculation, application/analysis, assumptions and communication. Each of these criteria is described in detail, and the performance rating system ranges from the highest level (4, or "capstone") through mid-range "milestones" (3, 2) to the beginner level (1). The rubric may be downloaded from the web; as with all its VALUE rubrics, AAC&U encourages institutions to modify this one to reflect local emphases. Dingman and Madison (2011) have developed a modified rubric based on AAC&U's prototype. Grawe et al. (2010) have published a rubric for assessing QR skills within the context of writing assignments.

With support from the National Science Foundation, the Dartmouth College MATC project has developed a 35-question attitude survey to explore how students feel about the subject of math and their comfort with using it. The project has also have developed an interview protocol for focus groups with students. This protocol not only addresses attitudes but the issue of integration of mathematics with the humanities in the course(s) students took, as well as their possible longer-term use of the skills they gained in the course.

It is important for universities to establish standards of performance that students should reach at or near graduation with respect to QR. This is a key part of the new WASC requirement for reporting on students' achievement in core competencies. Direct assessment of QR skills could be used (e.g., evaluation of e-portfolio collections of student work), along with other means, to determine the actual level of performance. Faculty could then apply their findings regarding performance to identify programmatic changes that need to be made to make improvements.

Learning, Teaching, and Faculty Development: There is no single pedagogy for QR, although problem-based or inquiry-focused learning approaches may be the most appropriate. Having students analyze data that is relevant to the course or discipline is a good place to start. News media are ready sources of data that can be used in classes. For example, Dingman and Madison (2011) take a student-centered approach to a general education course that moves the instructor into a moderator role, working with students on problems that stem from their interests and current events. Texts come primarily from the Internet. Grawe (2012) describes several resources for teaching and measuring QR, such as those provided by three national organizations, the Mathematical Association of America (MAA), Project Kaleidoscope (PKAL), and the National Numeracy Network (NNN). Their websites offer a variety of curricular materials, along with assessment resources. NNN also publishes a national journal, *Numeracy*, that "supports education at all levels that integrates quantitative skills across disciplines." This journal publishes the latest developments in QR education. In Volume 6, Issue 2, the theme is financial literacy, with nine articles describing a variety of education approaches, curricular materials, and assessment methods.

This type of teaching has implications for faculty development: not only do faculty members need to be comfortable with the content of QR, but they also need to become skilled in adapting real-world materials to instruction and using more active, less lecture-focused instructional methods. As the writing across the curriculum movement has learned, one of the best ways to help faculty members incorporate QR learning into their courses may be workshops sponsored by the faculty development center. These workshops can help faculty members gain confidence and skills in generating assignments and developing classroom activities for QR in disciplines that do not routinely use mathematics, such as in the arts and humanities. Faculty in these disciplines may also have math anxiety, much as faculty in the sciences and engineering may have anxiety about teaching and grading writing.

Conclusion. Hughes-Hallett (2001) asserts that what we need is a partnership among departments to help students achieve QR learning outcomes. She argues that this partnership must involve high schools, community colleges, colleges and universities. Before we get to that point, however, institutions need support as they address for themselves the complex issues regarding the development of QR outcomes, learning experiences, assessments, and faculty development programs. This WASC-sponsored workshop will explore the following themes through workshop and mentoring sessions delivered by experts in the field:

1. Defining Quantitative Reasoning
2. Quantitative Reasoning in General Education and across the Curriculum
3. Assessing Quantitative Reasoning
4. Faculty Development in Quantitative Reasoning
5. Supporting Students' Development of Quantitative Reasoning Skills

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Developing a Campus Culture that Embraces Assessment of Learning in Majors[1]

Jennifer A. Lindholm

Many, if not most, academics instinctively resist external pressures for change such as we are experiencing today with respect to providing new forms of "evidence" of student learning. In large part, this is because they see such mandates as a threat to institutional, program, and faculty autonomy. In cases like this, there is usually awareness within the academic community that something needs to be done. The creative challenge, then, is to mobilize an institutional effort (or efforts) that will be responsive to external pressures in ways that will also (a) further the college's or the university's educational mission and purpose (that is, the efforts are institutionally "meaningful"), (b) build on existing principles, priorities, and practices; and (c) be manageable for campus personnel, particularly faculty, to embark on and sustain. This essay addresses some common barriers to effective use of assessment in majors and professional fields of study and highlights key considerations for developing and sustaining program cultures that embrace new approaches to assessing their students' learning.

Barriers to Using Assessment Effectively

One barrier to effective use of assessment (outcomes-based or otherwise) in higher education institutions is our beliefs and assumptions about current programs and practices. Often we simply assume, for example, that what we are doing works, especially if the particular program is highly ranked. By assuming that traditional practice is efficacious (and, by implication, superior to any known alternative), we limit our capacity to improve our programs and to strengthen our capacity to positively impact student learning and development. If we fall into the trap of assuming that "no news is good news," over time we invariably will lose touch with teaching and learning needs and concerns. Ultimately, this disconnect

[1] This essay draws heavily from three prior essays (indicated with "*" in the reference list) that I authored or co-authored in association with my involvement in The Kellogg Forum on Higher Education Transformation, a collaborative that brought together academic leaders, researchers, and higher education institutions in an effort to enhance our understanding of institutional change and transformation. Selected text from one of those pieces in particular, *The Theory and Practice of Institutional Transformation* (Astin & Associates, 2001) was extracted and/or adapted for use here. Many of the principles our team identified then have been useful in my subsequent efforts related to UCLA's ongoing *Initiative to Evaluate the Effectiveness of Academic Programs for Undergraduate Students*.

compromises our potential to enhance students' learning experiences in what is arguably the most significant part of their college experience: their major or professional field.

Another significant challenge is the cognitive shift that often must take place in how we perceive assessment and how we respond to feedback. Anyone who has been involved with assessment initiatives on a campus knows that resistance may stem from a number of beliefs, including the notion that assessment activities are primarily for satisfying external audiences rather than for improving educational programs; resentment toward the time and resources that must be invested (especially today, given budgetary constraints that have painful implications for academic units and programs); skepticism over the quality and value of information collected; and fear that the results of assessment efforts will, in one way or another, be used against the program or faculty. Most often, it is some combination of such beliefs that creates resistance among those, especially faculty, whose input and support is most crucial for ensuring the success of student learning assessment initiatives in the major (see also, for example, Palomba & Banta, 1999).

Irrespective of institutional type or disciplinary context, the primary challenge is to create an environment that supports the belief that the role of assessment is to provide feedback as a means of promoting improvement in both student learning and program quality; as such, assessment is an integral part of responsible practice. Because assessment necessarily involves multiple actors and interest groups, it is also important to recognize the necessity of honest, on-going communication. When coupled with a commitment to open dialogue about process and outcomes, assessment also can become a tool for "values clarification," a preliminary step in establishing a culture of continuous improvement and ensuring a strong connection to the institution's mission and values.

"Exterior" and "Interior" Considerations in Assessment of Learning in Majors

Too often, we focus exclusively on *exterior* considerations associated with learning outcomes assessment. For example, how are students' achievement and behavior affected by the academic program? Are faculty members "cooperating" by engaging at least minimally in assessment? As a department or program, are we visibly doing "enough" so that we'll be able to pass muster during our next program or accreditation review? The problem with focusing exclusively on these types of questions is we ignore the fact that students and faculty, as well as other members of the academic and surrounding communities, also have *interiors*—beliefs, values, aspirations, and intents that vitally affect everything they do. The move to an assessment culture faces a very tenuous future if it is not accompanied by appropriate changes in the interiors of those who will be affected by the “structural” changes (for example, changes to program policies, curricula, or pedagogical practices). If key program personnel remain indifferent or opposed to changes that they will eventually have to help implement, it is unlikely that any transformation can be sustained. In other words, if sufficient numbers of program faculty persist in their indifference (or opposition) to attempts to implement new forms of assessment or to use assessment findings to inform curricular and programmatic development, they will in all likelihood succeed in sabotaging the effort.

If we regard the collective or *shared* values and beliefs of program personnel as the equivalent of “program culture,” then we can state the following principle: successful transformation of any program is always systemic; that is, it requires changes in both the program structures *and* culture(s). At the same time, it is essential for the program–level transformation to be supported and promoted by an analogous institution-level transformation. Recognizing and addressing the necessity for cultural change -- at all levels -- is critically important. In our haste to enact “quick fixes,” this critical consideration is all too often overlooked or under-emphasized.

While institutional history, turnover in key personnel, and lack of perceived “crisis” can all present potential obstacles to sustaining transformative efforts, considerations related to institutional and program cultures ordinarily pose the greatest challenge for reformers. There are, of course, many other more mundane shared beliefs that can pose serious obstacles to change: “Everyone’s too busy to take on anything new.” “The proposed reforms are too costly” (or simply “unfeasible.”) “It’s impossible to change anything around here.” “Maybe if we wait long enough, the issue will simply go away.” “The faculty senate will never go along with this.” It is not so much a question of whether or not such beliefs are in some sense “true,” but rather that if they remain unexamined, they can undermine any transformation effort. It is also important to realize that academic communities may share unrecognized beliefs that would actually support the type of change that is needed. For this reason alone, it is important at the outset of any transformation effort to initiate conversation that focuses on uncovering and reflecting on the complex beliefs systems that define the academic culture and its various subcultures.

One obvious strategy for facilitating cultural change, at any level, is to involve as many people and as many different organizational units as possible in the process. In this way, people become “informed through participation,” which helps to generate a sense both of ownership in the project and of identification with the goals and values that underlie it (Giola & Thomas, 2000). At the program level, involving people from diverse departments and units can not only stimulate new kinds of conversations, forge partnerships, and break down silos; in a spirit of “safety in numbers,” it can also provide psychological cover and make individual programs feel less vulnerable.

Another important strategy is simple patience and persistence, even in the face of passive resistance, which can assume many different forms but most often involves some minor (usually verbal) resistance coupled with simply “not doing” (or doing poorly or half-heartedly) whatever is needed to implement or sustain the change. In some cases, critics of the effort can be effectively encouraged to shift their critical energies away from attempts to undermine or defeat the transformation initiative and direct them instead towards improving and strengthening associated efforts. Throughout the process, expressing appreciation for the efforts and contributions of campus community members is critical, as is celebrating key accomplishments and milestones.

Planning for Success in Assessment of Majors

A useful planning exercise is to think ahead with the aim of anticipating some of the likely outcomes of the actual implementation phase. Ideally, such projections include “who,” “what,” “when,” “where,” “why,” and “how.” A plan should also address questions such as the following:

- What aspects of the plan are likely to be the easiest to implement?
- How is the change process most likely to “move through” the program?

- Where is the greatest resistance most likely to come from? How might we respond?

- Who will likely feel “left out” of the process? What options are available to give them a greater sense of involvement and ownership?

- What sorts of resource demands are likely to arise at various points in the implementation process?

- How will the assessment effort be communicated to the broader institutional community? Should special provisions be made to involve that community?

Tools and Strategies

There are many strategies that can be helpful in facilitating the transformation of a traditional program to one that is truly student-centered, focused on learning outcomes, committed to meaningful use of assessment, and dedicated to continuous improvement. Here are some suggested steps:

- Build on what the department or program is already doing and what is already congenial to the culture of the discipline. English will not approach assessment in the same way as sociology or nursing. Is there already a senior research project? A poster session? A capstone? A signature assignment? A comprehensive examination or senior declamation? Something else that serves as the culmination of the major? Activities like these can easily be used in existing or modified form to serve assessment purposes.
- Focus on a small number of agreed-upon outcomes that apply to all majors in the program. Specializations are welcome to articulate their own more particularized outcomes, but it is simpler to begin with a small number that are common across the program.
- Begin the assessment effort with an outcome or two that many faculty agree they would like to see improved, and that would tangibly raise the quality of their graduates overall. (For many programs, this is math skills, or writing, or ability to evaluate literature in the field.)

- Map the required curriculum, both as a prompt to conversation about what is or is not taught, and as a way to discover how consistently outcomes are introduced, developed, and brought to higher levels of mastery.
- Collect evidence in ways that are minimally intrusive and, to the greatest extent possible, use existing classroom assignments. Use sampling to keep analysis manageable. Think sustainability.
- If faculty feel strongly that they want to use a commercially available test (e.g., one of ETS' Major Field Tests), they should be supported in doing so, but the assessment effort should use multiple methods to get at other outcomes that are not amenable to multiple-choice testing (e.g. laboratory bench skills or patient interaction skills.)
- Involve as many faculty as practical in developing rubrics, training to use them, scoring of artifacts, and analyzing results.
- Have open, inclusive conversations about the findings; if they are controversial, be willing to discuss the shortcomings of the assessment but don't use that conversation as a way to avoid hard issues related to learning. Make sure that the department's willingness to acknowledge and deal with problems is praised and rewarded.
- Create a plan for dealing with any areas in which student performance is not at the level faculty would like to see. Be sure that administrators provide *some* level of support for the response.
- Make sure that there is follow-up, or what is known as "closing the loop." If a change is implemented, it's essential to go back in a year or two and see whether that change had the desired effect and actually improved student performance.
- Involve students! They can tell us things we have no other way of knowing.

Of course, on a more general level, it helps if the department or program can maintain open channels of communication with both internal and external audiences; connect with the institution's broader mission and values; use strategic planning to support the institution's mission and values while advancing its own quality; and engage consultants, as needed, to support faculty efforts, break up logjams, and offer fresh perspective. Program goals should also include developing a shared sense of the "whole" – that is, both how the program functions as a cohesive unit and how the program is part of the whole institutional enterprise; and cheerleading, both when efforts succeed and when colleagues are struggling with process. Working with peer programs at other institutions, obtaining external funding, presenting at scholarly meetings, and getting the go-ahead for new hires can also help greatly to convey status and legitimacy to program-level assessment efforts, while finger-pointing or assigning blame should be avoided at all costs.

Conclusion

Ultimately, the most powerful strategy for facilitating transformation is to show that assessment – and all the faculty effort that goes into it –*actually makes a difference*: it improves individual students' learning, raises the quality of the program's graduates as a whole, strengthens the program's retention, graduation, and graduate-school attendance rates; responds to the needs of local and regional employers as appropriate; enhances the reputation of the department; and attracts more majors. In the final analysis, the success of any program transformation to a culture of assessment will depend on a savvy mix of committed individuals, broader ownership, and shared learning, with the ultimate goal of *commitment*, rather than *compliance*, to the overall effort.

Suggested Readings

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Plenary

Look, It's Math, It's Statistics, It's History and Psychology! It's Quantitative Reasoning!

S. Elrod

Quantitative Reasoning: The Final Frontier of Core Competencies

Susan Elrod

California State University, Fresno

WASC QRAM Retreat
October 2-3, 2014

Look, it's math, it's statistics, its history and psychology! It's Quantitative Reasoning!

QR is a WASC CC

- The Five Core Competencies (CCs):
  - Writing
  - Oral Communication
  - **Quantitative Reasoning**
  - Critical Thinking
  - Information Literacy

WASC
Senior College and University Commission

QR is an AAC&U LEAP ELO

- **Quantitative reasoning** is one of the **LEAP** (Liberal Education for America's Promise) Essential Learning Outcomes (or **ELOs**) developed by the Association of American Colleges & Universities (AAC&U), along with **inquiry and analysis**, **critical and creative thinking, written and oral communication, information literacy and teamwork and problem solving.**

QF is in the DQP

- The Lumina Foundation's Degree Qualifications Profile (**DQP**) calls this skill **quantitative fluency** and places it, like LEAP, among several important intellectual skills**: analytic inquiry, information literacy, engaging diverse perspectives, and communication fluency**.

Some Definitions

A comfort, competency, and "habit of mind" in working with numerical data as being as important in today's highly quantitative society as reading and writing were in previous generations.

A ability that emphasizes the higher-order reasoning and critical thinking skills needed to understand and to create sophisticated arguments supported by quantitative data.

From the National Numeracy Network

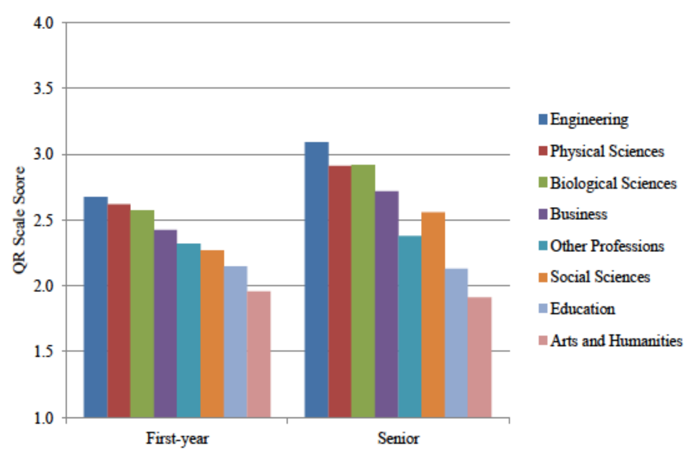
Traditional Math	QR
Abstract, deductive discipline	Practical, robust habit of mind
Employed in professions such as sciences, technology and engineering	Employed in every aspect of an alert, informed life
Rises above context	Anchored in context
Objects of study are ideals	Objects of study are data
Serves primarily professional purposes	Is essential for all graduates' personal and civic responsibilities

From "Everything I Needed to Know about Averages. . . I Learned in College" by Lynn Arthur Steen, professor of mathematics, St. Olaf College.

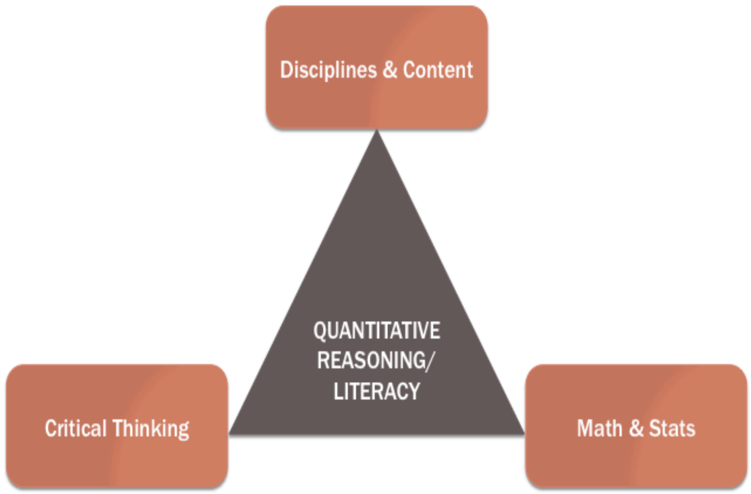
From Lumina's DQP

- Associate level:
  - Presents **accurate calculations and symbolic operations**, and **explains** how such calculations and operations are used in either his or her **specific field of study or in interpreting social and economic trends.**
- Bachelor's level:
  - Constructs **accurate and relevant calculations**, **estimates, risk analyses or quantitative evaluations of public information** and **presents them** in papers, projects or multi-media events.

Average Frequency of QR Activities by Major and Class Level (NSSE)



Where does QR fit in the Curriculum?



Challenges to Implementing QR

- Making sure it is part of the curriculum; most higher education students graduated without sufficient QR
- Faculty in all disciplines needed professional development support to enhance QR in their courses
- QR was not part of assessment activity
- Education policy leaders were insufficiently aware of the increasing need for QR

2001 Study by Mathematical Association of America (MAA)

Assessing QR

Rubrics

Standardized Tests

FOCUS GROUPS

Lab Reports

Embedded Exam Questions

Attitude Surveys

Standardized Tests

- **Quantitative Reasoning Skills Test (Sundre, 2008):** A 25-minute multiple-choice exam that focuses on two key outcomes, ability of students to:
  - use **graphical, symbolic, and numerical methods to analyze, organize and interpret natural phenomenon**; and
  - **discriminate between association and causation**, and identify the **types of evidence used to establish causation**.
- **Take the Scientific Literacy Concept Inventory:** http://tinyurl.com/WASCQROct2013

AAC&U's VALUE Rubric

QUANTITATIVE LITERACY VALUE RUBRIC

for more information, please contact value@aacu.org

Association of American Colleges and Universities

Definition

Quantitative Literacy (QL) – also known as Numeracy or Quantitative Reasoning (QR) – is a "habit of mind," competency, and comfort in working with numerical data. Individuals with strong QL skills possess the ability to reason and solve quantitative problems from a wide array of authentic contexts and everyday life situations. They understand and can create sophisticated arguments supported by quantitative evidence and they can clearly communicate those arguments in a variety of formats (using words, tables, graphs, mathematical equations, etc., as appropriate).

Evaluators are encouraged to assign a zero to any work sample or collection of work that does not meet benchmark (cell one) level performance.

	Capstone 4	Milestones 3	 2	 1
Interpretation *Ability to explain information presented in mathematical forms (e.g., equations, graphs, diagrams, tables, words)*	Provides accurate explanations of information presented in mathematical forms. Makes appropriate inferences based on that information. *For example, accurately explains the trend data shown in a graph and makes reasonable predictions regarding what the data suggest about future events.*	Provides accurate explanations of information presented in mathematical forms. *For instance, accurately explains the trend data shown in a graph.*	Provides somewhat accurate explanations of information presented in mathematical forms, but occasionally makes minor errors related to computations or units. *For instance, accurately explains trend data shown in a graph, but may miscalculate the slope of the trend line.*	Attempts to explain information presented in mathematical forms, but draws incorrect conclusions about what the information means. *For example, attempts to explain the trend data shown in a graph, but will frequently misinterpret the nature of that trend, perhaps by confusing positive and negative trends.*
Representation *Ability to convert relevant information into various mathematical forms (e.g., equations, graphs, diagrams, tables, words)*	Skillfully converts relevant information into an insightful mathematical portrayal in a way that contributes to a further or deeper understanding.	Competently converts relevant information into an appropriate and desired mathematical portrayal.	Completes conversion of information but resulting mathematical portrayal is only partially appropriate or accurate.	Completes conversion of information but resulting mathematical portrayal is inappropriate or inaccurate.
Calculation	Calculations attempted are essentially all successful and sufficiently comprehensive to solve the problem. Calculations are also presented elegantly (clearly, concisely, etc.)	Calculations attempted are essentially all successful and sufficiently comprehensive to solve the problem.	Calculations attempted are either unsuccessful or represent only a portion of the calculations required to comprehensively solve the problem.	Calculations are attempted but are both unsuccessful and are not comprehensive.
Application / Analysis *Ability to make judgments and draw appropriate conclusions based on the quantitative analysis of data, while recognizing the limits of this analysis*	Uses the quantitative analysis of data as the basis for deep and thoughtful judgments, drawing insightful, carefully qualified conclusions from this work.	Uses the quantitative analysis of data as the basis for competent judgments, drawing reasonable and appropriately qualified conclusions from this work.	Uses the quantitative analysis of data as the basis for workmanlike (without inspiration or nuance, ordinary) judgments, drawing plausible conclusions from this work.	Uses the quantitative analysis of data as the basis for tentative, basic judgments, although is hesitant or uncertain about drawing conclusions from this work.
Assumptions *Ability to make and evaluate important assumptions in estimation, modeling, and data analysis*	Explicitly describes assumptions and provides compelling rationale for why each assumption is appropriate. Shows awareness that confidence in final conclusions is limited by the accuracy of the assumptions.	Explicitly describes assumptions and provides compelling rationale for why assumptions are appropriate.	Explicitly describes assumptions.	Attempts to describe assumptions.
Communication *Expressing quantitative evidence in support of the argument or purpose of the work (in terms of what evidence is used and how it is formatted, presented, and contextualized)*	Uses quantitative information in connection with the argument or purpose of the work, presents it in an effective format, and explicates it with consistently high quality.	Uses quantitative information in connection with the argument or purpose of the work, though data may be presented in a less than completely effective format or some parts of the explication may be uneven.	Uses quantitative information, but does not effectively connect it to the argument or purpose of the work.	Presents an argument for which quantitative evidence is pertinent, but does not provide adequate explicit numerical support. (May use quasi-quantitative words such as "many," "few," "increasing," "small," and the like in place of actual quantities.)

Rubric for QR in Writing

Quantitative Reasoning in Student Writing Rating Sheet

I. Identification. **Student I.D. #: ________________ Reader I.D. #: _____**

II. Is QR potentially relevant to this paper? [rate potential contents of paper, not the assignment]

___NO or incidentally only ___YES, but peripherally only ___ YES, centrally

III. What is the extent of numerical evidence and quantitative reasoning present in the paper? [See: "Employs QR Criteria"; Note: This is *not* a rating of the quality of the QR shown, only its presence.]

___ rating of 1-3, review attached criteria

IV. OVERALL ASSESSMENT of Quality of implementation, interpretation, and communication of QR:

___ rating of 1-4, review attached criteria

V. Problematic characteristics of the QR present in the paper: [check all issues that detract significantly from the reader's understanding of the information presented.]

___Uses ambiguous words rather than numbers.

___Fails to provide numbers that would contextualize the argument.

___Fails to describe own or others' data collection methods.

___Doesn't evaluate source or methods credibility and limitations.

___Inadequate scholarship on the origins of quantitative information cited.

___Makes an unsupported claim about the causal meaning of findings.

___Presents numbers without comparisons that might give them meaning.

___Presents numbers but doesn't weave them into a coherent argument.

VI. Does the assignment explicitly call for the use of QR in the paper?

___YES ___NO ___NO ASSIGNMENT PRESENT

Figure 1. Scoring rubric.

Grawe, N. D., N. S. Lutsky, and C. J. Tassava. 2010. "A Rubric for Assessing QR in Written Arguments." *Numeracy* 3, no. 1,

Quantitative Reasoning Program at Bowdoin College

- **Assessing** first-year students' quantitative literacy
- **Advising** students regarding appropriate quantitative courses
- Establishing **study groups** for quantitative courses
- Providing **individual tutoring** for students in quantitative courses
- Offering **supplemental support** to quantitative courses

Retreat Goals for QR

- To help you with:
  - Defining Quantitative Reasoning
  - Establishing Quantitative Reasoning in General Education and across the Curriculum
  - Assessing Quantitative Reasoning
  - Designing Faculty Development in Quantitative Reasoning
  - Supporting Students’ Development of Quantitative Reasoning Skills

WASC Senior College and University Commission | EDUCATIONAL PROGRAMS

Breakout 1

Developing and Evaluating QR Courses

B. Madison

What's a QR Course?

Bernie Madison
University of Arkansas

Goals for Our Students

- Critical consumers of numbers (quantities)
  - Is it reasonable?
  - Is it unusual? How surprised should we be?
  - Is it correct?
  - Is it meaningful?
  - How was it determined?
- Careful and effective users of numbers
  - Quantitative arguments
  - Assessing risk
  - Measuring change
- Attentive to units
  - Numbers are adjectives


Frank & Ernest
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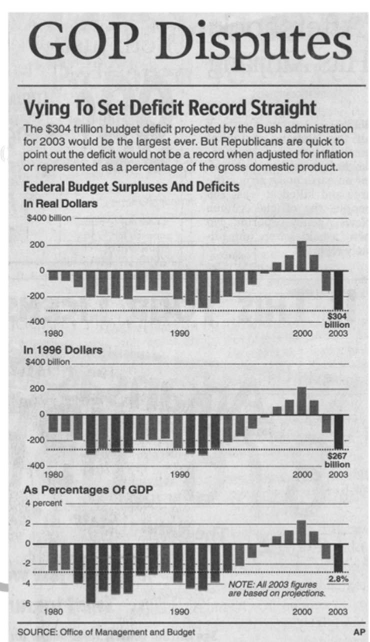
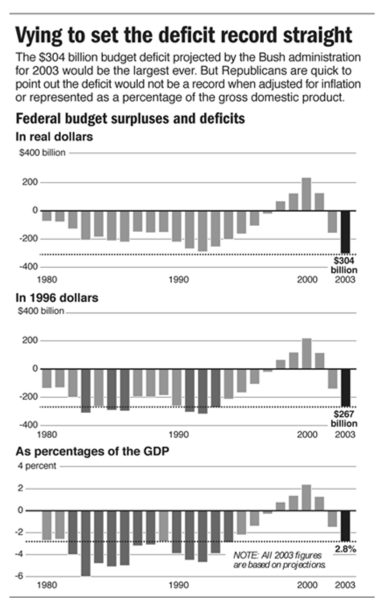
12-29
THAVES


GOP Disputes
Vying To Set Deficit Record Straight
The $304 trillion budget deficit projected by the Bush administration for 2003 would be the largest ever. But Republicans are quick to point out the deficit would not be a record when adjusted for inflation or represented as a percentage of the gross domestic product.
Federal Budget Surpluses And Deficits
In Real Dollars
$400 billion
200
0
-200
-400
$304 billion
1980
1990
2000
2003
In 1996 Dollars
$400 billion
200
0
-200
-400
$267 billion
1980
1990
2000
2003
As Percentages Of GDP
4 percent
2
0
-2
-4
-6
2.8%
NOTE: All 2003 figures are based on projections.
1980
1990
2000
2003
SOURCE: Office of Management and Budget
AP


Vying to set the deficit record straight
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Federal budget surpluses and deficits
In real dollars
$400 billion
200
0
-200
-400
$304 billion
1980
1990
2000
2003
In 1996 dollars
$400 billion
200
0
-200
-400
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1980
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As percentages of the GDP
4 percent
2
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1990
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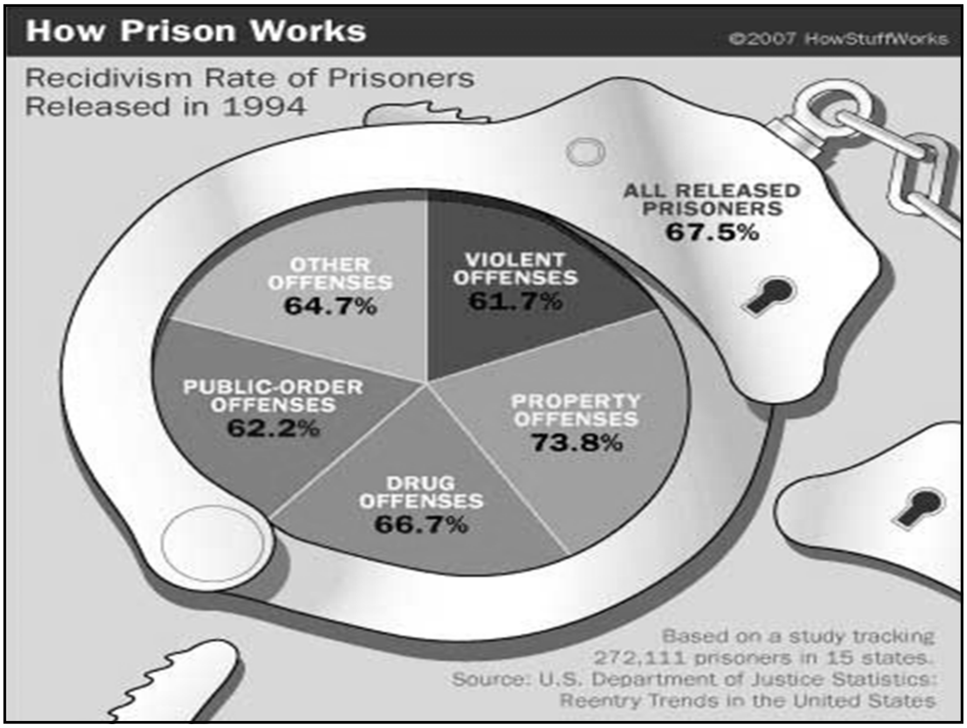

How Prison Works
©2007 HowStuffWorks
Recidivism Rate of Prisoners
Released in 1994
ALL RELEASED
PRISONERS
67.5%
OTHER
OFFENSES
64.7%
VIOLENT
OFFENSES
61.7%
PUBLIC-ORDER
OFFENSES
62.2%
PROPERTY
OFFENSES
73.8%
DRUG
OFFENSES
66.7%
Based on a study tracking
272,111 prisoners in 15 states.
Source: U.S. Department of Justice Statistics:
Reentry Trends in the United States


Our
Chicken
contains
up to
5
times less
Sodium!

Units matter….

…. a lot

Smart

My dad gave me one dollar bill
'Cause I'm his smartest son,
And I swapped it for two shiny quarters
'Cause two is more than one!

And then I took the quarters
And traded them to Lou
For three dimes -- I guess he don't know
That three is more than two!

Just then, along came old blind Bates
And just 'cause he can't see
He gave me four nickels for my three dimes,
And four is more than three!

And I took the nickels to Hiram Coombs
Down at the seed-feed store,
And the fool gave me five pennies for them,
And five is more than four!

And then I went and showed my dad,
And he got red in the cheeks
And closed his eyes and shook his head--
Too proud of me to speak!

- Shel Silverstein

Context matters!

HISTORY

The Legacy of Little Rock. Even after 50 years, most U.S. schools are still racially separate and too often unequal

BY JUAN WILLIAMS

THE 50TH ANNIVERSARY OF THE LITTLE Rock school crisis is a powerful lesson in the complicated calculus of social change. People on all sides of the civil rights issues in 1957 were shocked by the sight of white mobs and the Arkansas National Guard, under orders from Governor Orval Faubus, blocking nine black children from entering the city's Central High School. When President Dwight Eisenhower sent in the 101st Airborne to protect the students, some feared this and other efforts to desegregate the nation's schools might signal the start of a second civil war. But the Governor backed down, and on Sept. 25 the nine became the first blacks to enroll at the high school.

Earlier this year the U.S. Mint issued a silver dollar commemorating the event, and throughout the anniversary's week there will be other observations marking this turning point in U.S. history. But the joy will be somewhat muted, for American schools are still nearly as segregated as they were 50 years ago. Almost three-quarters of African-American students are currently in schools that are more than 50% black and Latino, while the average white student goes to a school that is 80% white, according to a 2001 study by the National Center for Education Statistics. Similarly, a 2003 study by the Civil Rights Project at Harvard found that 27 of the nation's largest urban school districts are "overwhelmingly" black and Latino, and segregated. The percentage of white students going to school with black students is "lower in 2000 than it was in 1970 before busing for racial balance began," the report said.

And public education in the U.S. is not only separate, it is often unequal. In 2005 the New York *Times* reported that the average black or Latino student graduating from high school "can read and do arithmetic only as well as the average eighth-grade white student." At the same time, on average, white elementary-school-age children go to schools in which about a third of the students qualify for free or low-cost lunches, while the typical black or Latino grade-schooler attends one in which two-thirds of children are in the reduced-price lunch program.

The clear evil of racism explained the gaps in opportunities and achievement between black and white children back in 1957. But that kind of open malice is harder to find today, and the reasons for current discrepancies are more complicated and more challenging. At the time of Little Rock, no one could foresee that Hispanics would become the nation's largest minority and perhaps its most segregated group, but both are true today. It is also true that white flight and now the exodus of middle-class black families fleeing to the suburbs to escape crime have continued to take good students and active parents away from city schools. But an even larger factor in early 21st century America is the declining number of school-age white children and increasing number of school-age minorities. Such demographic shifts are making it even more difficult to integrate American schools by race or class.

These realities have become an issue in recent court decisions. Judges point to high levels of residential segregation as the root cause of school segregation and question the wisdom of using children and schools to remedy adults' preferences for isolating themselves by income and race. This year the Supreme Court ruled that voluntary school-integration plans in Seattle and Louisville, Ky., violated the rights of students to be judged on individual merit even if the ruling means that many schools remain segregated by race and class. It was a sad decision, acknowledging the defeat of the ideals and aspirations of Little Rock and the 1954 *Brown v. Board of Education* decision that made segregation illegal. But it should also be hailed for acknowledging new realities: first, even as we celebrate what happened 50 years ago in the glory days of the civil rights movement, the political will to integrate schools in this country is long gone. So, too, is the desire to fix every economic inequity before delivering quality education to all children.

But there is hope. Fifty years after critics charged one Republican President with risking a civil war by sending federal troops into a Southern city to enforce integration, a Republican President is taking on the problem of underperforming big-city schools and what he calls the "bigotry of low expectations." President George W. Bush is seeking renewal of the No Child Left Behind law, which holds schools accountable for teaching every student and narrowing the achievement gap regardless of a child's color, income or family background. Despite its shortcomings, like training students how to pass standardized tests instead of instructing them how to think critically, the President's plan is worthy simply for insisting that all children can learn. Fifty years after U.S. troops had to escort nine black children to school in Little Rock, the issue is still how to take race out of the equation when it comes to educating every American child. ■

Williams is a senior correspondent for NPR, an analyst for Fox News and the author of Enough

Uncivil A mob taunted Elizabeth Eckford on her way to Central High in 1957

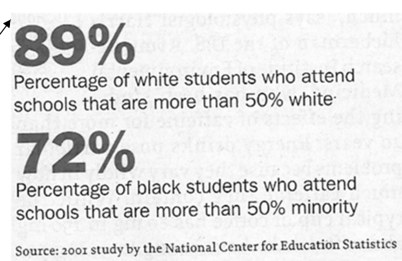
89%
Percentage of white students who attend schools that are more than 50% white

72%
Percentage of black students who attend schools that are more than 50% minority

Source: 2001 study by the National Center for Education Statistics

TIME October 1, 2007

61



89%
Percentage of white students who attend schools that are more than 50% white

72%
Percentage of black students who attend schools that are more than 50% minority

Source: 2001 study by the National Center for Education Statistics

What $1.2 Trillion Can Buy

The human mind isn't very well equipped to make sense of a figure like $1.2 trillion. We don't deal with a trillion of anything in our daily lives, and so when we come across such a big number, it is hard to distinguish it from any other big number. *Millions, billions, a trillion — they all start to sound the same.*

DAVID LEONHARDT

ECONOMIX

The way to come to grips with $1.2 trillion is to forget about the number itself and think instead about what you could buy with the money. When you do that, a trillion stops sounding anything like millions or billions.

For starters, $1.2 trillion would pay for an unprecedented public health campaign — a doubling of cancer research funding, treatment for every American whose diabetes or heart disease is now going unmanaged and a global immunization campaign to save millions of children's lives.

Combined, the cost of running those programs for a decade wouldn't use up even half our money pot. So we could then turn to poverty and education, starting with universal preschool for every 3- and 4-year-old child across the country. The city of New Orleans could also receive a huge increase in reconstruction funds.

The final big chunk of the money could go to national security. The recommendations of the 9/11 Commission that have not been put in place — better baggage and cargo screening, stronger measures against nuclear proliferation — could be enacted. Financing for the war in Afghanistan could be increased to beat back the Taliban's recent gains, and a peacekeeping

One option is beating tanks into universal preschool.

force could put a stop to the genocide in Darfur.

All that would be one way to spend $1.2 trillion. Here would be another:

The war in Iraq.

In the days before the war almost five years ago, the Pentagon estimated that it would cost about $50 billion. Democratic staff members in Congress largely agreed.

Lawrence Lindsey, a White House economic adviser, was a bit more realistic, predicting that the cost could go as high as $200 billion, but President Bush fired him in part for saying so.

These estimates probably would have turned out to be too optimistic even if the war had gone well. Throughout history, people have typically underestimated the cost of war, as William Nordhaus, a Yale economist, has pointed out.

But the deteriorating situation in Iraq has caused the initial predictions to be off the mark by a scale that is difficult to fathom. The operation itself — the helicopters, the tanks, the fuel needed to run them, the combat pay for enlisted troops, the salaries of reservists and contractors, the rebuilding of Iraq — is costing more than $300 million a day, estimates Scott Wallsten, an economist in Washington.

That translates into a couple of billion dollars a week and, over the full course of the war, an eventual total

Continued on Page 8

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One Model of a QR Course

Calculation a la Best		**Beyond Calculation (QL)**
	AAC&U Core Competencies	
Calculation[1]	← Representation Analysis/Synthesis →	Interpretation Assumptions Communication
	Arkansas QL1 Course	
Rational numbers Ratio Linear change Exponential change Statistical averages Statistical spreads Rates Counting Probability Mental arithmetic Measurement & units	↔ Representation	Habit of mind Productive disposition Writing Critical reading Argument & evidence Quantitative benchmarks Contextual accuracy Social constructions Economic constructions Comparative analysis Political constructions

Possible Sets of Criteria

- The six core competencies for QL -- AAC&U QL rubric
- The five strands of mathematical proficiency from *Adding It Up*
- The eight Standards for Mathematical Practice of CCSSM
- The five elements of effective thinking -- Burger and Starbird
- Three principles from *How People Learn*
- Ten principles from applying the science of learning to university teaching and beyond

QR Course Design Principles

1. *Provide a venue for continued practice beyond the course (and beyond school).*

2. *Keep the material relevant to students' everyday contemporary world*

3. *Use multiple contexts to practice quantitative reasoning.*

4. *Promote appreciation of arithmetical precision and the power of mathematical concepts and processes.*

5. *Help students to structure their quantitative reasoning in resolving problematic situations, including ample doses of critical reading and writing.*

6. *Encourage on-the-fly calculations and estimations.*

7. *Increase students' supplies of quantitative benchmarks.*

8. *Encourage students to use technology to enhance and expedite understanding.*

9. *Allow student interests to emerge.*

10. *Provide interactive classroom environment.*

To appear in Summer 2014 issue of *Peer Review*

Beyond Calculation

Bernard L. Madison, professor of mathematics, University of Arkansas
David Deville, graduate student in mathematics, University of Arkansas

Ten years ago, the first author wrote "Two Mathematics: Ever the Twain Shall Meet?" (Madison 2004) for an issue of *Peer Review* that focused on quantitative literacy (QL). In the ensuing decade QL, now referred to by many as quantitative reasoning, has gained considerable recognition as an effort by colleges and universities to ready their graduates for life in the quantitatively demanding US society. In many ways, the quantitative demands of that society differ from the disciplinary world of academe, adding significant challenges to education for QL. Just what kind of course or program can prepare students for confronting the myriad quantitative issues in their everyday lives, saying nothing about the demands of their chosen professions?

A DECADE OF PROGRESS

Before we look at some principles to consider and possible course models, we note some progress in QL education over the past decade. Starting in 2000, historian Robert Orrill and mathematician Lynn Steen led an initiative to promote better education for QL in high school and the early years of college. Part of that initiative was the creation of the National Numeracy Network (NNN), initially conceived as a confederation of QL centers but reconstituted as an interdisciplinary membership organization in 2004. Now NNN has hundreds of members and its journal, *Numeracy: Advancing Education in Quantitative Literacy*, is publishing in 2014 its seventh volume of two issues annually. Textbooks aiming at QL and instruments for assessing QL have been written, scores of institutions have added courses or learning centers for QL, some institutions have integrated QL across the curriculum, and the Mathematical Association of America has created a special interest group in QL that is noting its tenth anniversary this year. QL is becoming accepted as an expected learning outcome of college. For example, the Arkansas Department of Higher Education approved the inclusion of a QL course as part of the State Minimum Core of collegiate courses as an alternative to college algebra for students not majoring in science, engineering, or mathematics.

In 2009, AAC&U's Valid Assessment of Learning in Undergraduate Education (VALUE) project included QL as one of its ten intellectual and practical skills and developed a rubric for assessing QL at the institutional level. Subsequently modified by Boersma et al. (2011) for assessing individual student work, the rubric identified six core competencies for QL: interpretation, representation, calculation, analysis/synthesis, assumptions, and communication. These VALUE rubric core competencies, described below, provide a way to structure students' work toward QL and a guide for developing instructional materials, as well as a framework of an assessment instrument.

- *Interpretation*: Ability to glean and explain mathematical information presented in various forms (e.g., equations, graphs, diagrams, tables, words).
- *Representation*: Ability to convert information from one mathematical form (e.g., equations, graphs, diagrams, tables, words) into another.
- *Calculation*: Ability to perform arithmetical and mathematical calculations.
- *Analysis/Synthesis*: Ability to make and draw conclusions based on quantitative analysis.
- *Assumptions*: Ability to make and evaluate important assumptions in estimation, modeling, and data analysis.
- *Communication*: Ability to explain thoughts and processes in terms of what evidence is used, and how it is organized, presented, and contextualized.

CHALLENGES THAT REMAIN

The progress toward better QL education has been significant, driven by the recognition that QL is absolutely necessary for understanding democratic processes and thriving in a rapidly moving, economically volatile US society. Yet, significant educational questions remain. What learning theory best identifies issues in QL? Is it situated learning, since, from our view, all QL learning is situational or contextual? What pedagogy is most effective for QL education? What is/are the community/ies of practice for QL? How should QL fit into higher education? In mathematics? In statistics? Across the curriculum? Elsewhere?

Currently, in K-12, QL depends almost completely on the mathematics strand, and in higher education, many QL courses are housed in mathematical science departments or interdisciplinary learning centers. As of now, there are no established guidelines for QL courses and no accepted, effective measures of long-term retention and transfer. Mathematics and statistics courses are usually described by their content (e.g. calculus, differential equations, probability or experimental design). And mastery of content is the measure of success. Such a description for a QL course is elusive, as the mathematical and statistical content needed for QL currently does not have a clear description and consequently varies from course to course. In the absence of accepted mathematical content and measures of success, one must look elsewhere for building or evaluating QL courses. The first author (Madison 2014) has described such a process that stems from evaluating a QL course at the University of Arkansas that is housed in the mathematical sciences department.

MATHEMATICS AS SENSIBLE, USEFUL, AND WORTHWHILE

At about the time "Two Mathematics" was published in *Peer Review* ten years ago, a QL course was introduced at the University of Arkansas and has been evolving since.

Dingman and Madison (2011) wrote for this journal that teaching this course altered their perspectives on several things, including the role of the instructor, relevant mathematical content, use of technology, and sense-making in the messy world of realism. In the past three years our QL faculty members have begun to understand better the structure of QL courses and some guiding principles that seem necessary.

At the current time, there are two Arkansas QL courses: one with college algebra as a prerequisite and another that is an alternative to that course, which in this article will be referred to as QL1. The QL1 course was developed in 2012 using design principles derived from eight years of experience with the other QL course with a college algebra prerequisite. These design principles are supported by research findings about student learning (National Research Council 2000, 2001; Halpern and Hakel 2003). QL1 has two primary goals: (1) encourage students to develop habits of mind to analyze the quantitative content of everyday occurrences, and (2) increase students' productive disposition—that is, the habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one's own efficacy. Productive disposition is one of the strands of mathematical proficiency from the *Adding It Up* report of the National Research Council (2001) and its absence is a major barrier for QL in many math-phobic students.

Relevant Design Principles for a QL Course

Briefly, the design principles for a QL course are as follows:

Provide a venue for continued practice beyond the course (and beyond school). Quantitative reasoning is a habit of mind, and habits are developed by practice. One or two courses or four years of school can only prepare one for practicing QL. The venue for continued practice in the Arkansas course is media articles.

Keep the material relevant to students' everyday contemporary world. According to John Dewey, "School should be less about preparation for life and more about life itself." Connecting classroom learning to the everyday contemporary world not only can enhance learning in the classroom but can also lead students to adapt their classroom learning to the changing environment of everyday life. Relevance promotes productive disposition, noted above as a primary goal, and keeps material fresh.

Use multiple contexts to practice quantitative reasoning. According to Halpern and Hakel (2003), "The purpose of formal education is transfer" (38). Halpern and Hakel go on to identify retrieval in multiple contexts as one of the most basic principles for enhancing long-term retention and transfer of learning and indicate that periodically spaced, not massed, practice at retrieval is best.

Promote appreciation of arithmetical precision and the power of mathematical concepts and processes. This principle is often difficult to apply in a course where the main goal is to understand contextual situations with quantitative content. Nevertheless, when opportunities arise to make use of mathematical power by developing some algebra, doing so, when needed, shows students the power and utility of mathematics, getting at half of the dual nature of productive disposition.

Help students to structure their quantitative reasoning in resolving problematic situations, including ample doses of critical reading and writing. One way to do this is by using the QL core competencies of interpretation, representation, calculation, analysis/synthesis, assumptions, and communication (Carey 2009; Boersma et al. 2011). Critical reading is the foundation of interpretation, and writing promotes reflection and clear understanding.

Encourage on-the-fly calculations and estimations. If students are able to assess quickly the validity of a quantitative assertion or mentally compute a numerical result, then they will be better able to practice QR in their daily lives. Practice should become reflexive and habitual.

Increase students' supplies of quantitative benchmarks. Personal quantitative benchmarks are quantities that a student understands. For example, a student may understand a speed of 60 miles per hour (MPH) but not 1200 MPH. Such benchmarks are critical for understanding quantities (e.g. 1200 MPH is 20 times 60 MPH) and being able to determine reasonableness of quantitative assertions or numerical answers to questions. Providing multiple contexts for the use of benchmarks increases the chances that students retain the benchmarks and recognize their utility.

Encourage students to use technology to enhance and expedite understanding. Technology, including personal devices, is omnipresent in students' everyday lives, so it should be leveraged in service of understanding QL.

Allow student interests to emerge. As reported in *How People Learn*, "Students are motivated to spend time needed to learn complex problems that they find interesting. Opportunities to use knowledge to create products and benefits for others are particularly motivating for students" (National Resource Council 2000, 77). Again, this promotes productive disposition.

Provide an interactive classroom environment. Interactive classrooms engage students in sense-making activities and promote personal accountability. Successful QL students are able to step outside of their comfort zones and assume responsibility for their work. Further, if we intend for students to use QL outside of the classroom, possibly in discussions of public issues, then the classroom experience should provide preparation for this practice.

CALCULATION AND BEYOND

At the 2007 Wingspread interdisciplinary QL workshop, considerable discussion focused on the role of mathematical methods and calculations in QL. Sociologist Joel Best (2008A) considered calculation "to encompass all of the practices by which mathematical problems are framed and then solved" (125), or what mathematics classes center on. Best went on to argue that QL courses should go beyond calculation to include issues surrounding constructions—more specifically, social constructions.

We broaden Best's view a bit and consider a model of a QL course that consisting of two components: our model includes calculation, in the sense described by Best, and but also goes beyond calculation to encompass the many issues and dispositions involved in twenty-first-century QL in the United States. By "beyond calculation" we mean to include contributions from the arts, humanities, social sciences, natural sciences, public media, and entertainment— any area of human activity. As a mathematics course, the calculation component is unusual in the sense that it is fragmented, without any obvious unifying concepts. Further, the mathematical concepts and methods in the Arkansas QL1 course do not necessarily include concepts and methods of other QL courses that may be directed at different audiences. The Arkansas QL1 course is directed toward the general education of students in majors other than science, engineering, or business.

Because the mathematics of the QL1 course is largely from the K–12 curriculum, it could be seen as developmental. However, the sophistication of the course is in the "beyond calculation" component—echoing Lynn Steen's characterization of QL as sophisticated uses of elementary mathematics and statistics.

In table1, the top rectangle represents resolving a canonical QL situation using the AAC&U core competencies. One encounters a QL situation—say in a media article about economics—interprets the quantitative content, and produces a mathematical representation—say a linear equation. Then the problem becomes one of calculation. After the calculation and the results are analyzed and assumptions evaluated or noted, the results are communicated. This illustrates the habit of mind we want our students to develop. One of the major obstacles to developing this habit is a low level of productive disposition—the ability to see calculation as useful and have the confidence and skill to use it to understand the situation. Also, observing and critiquing this process can be difficult, especially since many students are comfortable with their traditionally passive roles in the mathematics classroom.

Table 1. The Arkansas QL1 Course—Calculation and Beyond

Calculation a la Best		Beyond Calculation (QL)
	AAC&U Core Competencies	
Calculation[1]	← Representation Analysis/Synthesis →	Interpretation Assumptions Communication
	Arkansas QL1 Course	
Rational numbers Ratio Linear change Exponential change Statistical averages Statistical spreads Rates Counting Probability Mental arithmetic Measurement & units	↔ Representation	Habit of mind Productive disposition Writing Critical reading Argument & evidence Quantitative benchmarks Contextual accuracy Social constructions Economic constructions Comparative analysis Political constructions

[1]Calculation here is one of the QL core competencies and differs somewhat from the component of the same name as articulated by Joel Best (2008A).

Some of the items in the beyond calculation component are familiar, but some are not. Neil Lutsky and colleagues (2008) have written extensively about the use of quantitative evidence in argument in student writing at Carleton College. Joel Best (2008B) has noted the importance of statistical benchmarks—broadened here to go beyond statistics—in understanding US social statistics. Economic constructions, such as the various stock indices, appear frequently in the media, and yet they are mysterious to most people. Political constructions that require QL often arise in disagreements about or differing views of budgetary situations—for example, the expression of the annual federal budget deficit in nominal dollars or as a percent of the gross domestic product. And graduates will frequently encounter comparative analyses, which usually require ad hoc methods. For example, comparing two credit card offers often comes down to individual preferences or expected uses, as the specifics of the offers are not directly comparable.

FINAL THOUGHTS

For quite some time, "quantitative reasoning" has been an accepted learning outcome of college, often without exemplification or clarification and frequently without authentic assessment. As US society has become immersed in quantification and quantitative analyses, specific and intentional QL education efforts have become essential. Over the past decade these efforts have been taking shape, but they remain varied and largely unevaluated. Communities of practice are forming, and research on QL learning is deepening. Professional societies, most notably AAC&U, the National Numeracy Network, and the Mathematical Association of America, lead many of these efforts. Most colleges and universities have created educational responses―courses, cross-curricular programs, or learning centers. Frameworks for QL courses are emerging, presaging standards for evaluation and some coherence, transferability, and expansion of learning. Many of the developments in QL education are described in the NNN journal *Numeracy* available at http://scholarcommons.usf.edu/numeracy/. Significant progress has marked the decade since the 2004 QL issue of *Peer Review*, but the educational ground is fertile for better understanding of QL and ways to help students achieve it. Informed participation in US society and individual prosperity depend greatly on those outcomes.

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How Does One Design or Evaluate a Course in Quantitative Reasoning?

Abstract
In the absence of generally accepted content standards and with little evidence on the learning for long-term retrieval and transfer, how does one design or evaluate a course in quantitative reasoning (QR)? This is a report on one way to do so. The subject QR course, which has college algebra as a prerequisite and has been taught for 8 years, is being modified slightly to be offered as an alternative to college algebra. One modification is adding a significant formal writing component. As the modification occurs, the current course and the modified one are judged according to six sets of criteria: the six core competencies of the Association of American Colleges and Universities rubric on quantitative literacy; the five mathematical competencies from the National Research Council (NRC) study report, *Adding It Up*; the eight practice standards from the Common Core State Standards for Mathematics; the five elements of effective thinking as articulated by Edward Burger and Michael Starbird, the summary research findings on human cognition from the NRC study report, *How People Learn*; and the ten principles gleaned from applying the science of learning to university teaching. The QR course, as described by ten design principles, is determined to be generally well aligned with most of the overlapping criteria of the six sets, providing cogent evidence of high educational value.

Keywords
QR course, Design Criteria

Cover Page Footnote
Bernard L. Madison is professor and former Chair of the Department of Mathematical Sciences, University of Arkansas, and former Dean of its Fulbright College of Arts and Sciences. He was founding president of the National Numeracy Network and is a frequent contributor to this journal.

Introduction[1]

Over the past decade or so, education for quantitative literacy (QL) or quantitative reasoning (QR) in the US has gained limited recognition as a critical and perhaps distinct component of school and college curricula, but effective educational methods for QR are tentative and unproven.[2] Focused around the publication of *Mathematics and Democracy* in 2001, several authors (e.g., Steen 1997 and 2001; Madison and Steen 2003 and 2008a), have made the case forcefully for QR education. Various post-secondary professional societies, notably the Mathematical Association of America (MAA 2004), Association of American Colleges and Universities (AAC&U 2004), the American Association of Two Year Colleges (AMATYC) (Blair 2006), and the National Numeracy Network (NNN),[3] have initiated policies and structures supporting QR education. Courses are being offered or are under development at individual colleges and universities, and consortia of institutions are working in concert to produce effective college level courses in QR, some in conjunction with developmental mathematics and statistics. Two of the efforts by consortia are centered at the Charles A. Dana Center[4] at the University of Texas in Austin and at the Carnegie Foundation for the Advancement of Teaching[5] in Palo Alto, California.

QR education in post-secondary institutions has two major resource hurdles to overcome. First, it has no academic home in either K-12 or post-secondary education (Madison 2001; Steen 2001). In K-12 QR education is highly dependent on the mathematics and statistics curricular strand, and less so on the sciences. Most post-secondary courses and quantitative learning centers (Madison and Steen 2008b; Gillman 2006) have evolved from mathematics or statistics units, but QR units and courses remain largely marginalized in college and university mathematics curricula. In contrast to most mainline collegiate disciplines, collegiate mathematics has long used its standard content-designated courses as general education courses – algebra, geometry, and calculus. Most collegiate mathematics courses have titles derived from the mathematical content of the course – e.g., calculus, differential equations, linear algebra. College and university mathematics faculty members, not unlike many of their colleagues in other STEM (science, technology, engineering, and mathematics) disciplines, have limited and varying interests in the role of their courses in service of general education. Various attempts at general education mathematics courses over the past century have met with limited acceptance, so mathematics faculty are strongly influenced by this in considering

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[1] This paper is a significant revision of a manuscript that was published as "Reverse Engineering a Course in Quantitative Reasoning" in *Quantitative Reasoning in Mathematics and Science Education: Papers from an International STEM Research Symposium (*R. L. Mayes and L. L. Hatfield, eds.), p. 43-64, vol. 3, WISDOM Monograph, 2013, Laramie, WY: College of Education, University of Wyoming.

[2] In the remainder of this paper QR will be used for either QL or QR except when referring to existing literature that uses QL.

[3] http://serc.carleton.edu/nnn/index.html. (all links in the footnotes were accessed 1 May 2014).

[4] http://www.utdanacenter.org/amdm/index.php

[5] http://www.carnegiefoundation.org/quantway

and supporting courses such as QR. The titles of such courses do not describe the mathematical content, so faculty are justifiably puzzled by what they are and how effective they would be in promoting learning in mathematics. (One of the author's colleagues characterized the content of the QR course as "fluff.") Mathematics in grades 9-16, from high school through the early years of college, is very linear, equaled only by that of a foreign language, and general education courses have no established place in this linearity (Madison 2003).

The second major resource hurdle for QR education is connected to the first. There are no clear guidelines for courses and no generally accepted measures of success. Consequently there are no widely accepted curricular materials.

Both of these hurdles were obvious when mathematical sciences faculty at the University of Arkansas considered[6] whether or not to establish a QR course as an alternative to college algebra for students who would not study further mathematics that needed many of the methods of college algebra, i.e. many of the students who were majoring in non-STEM disciplines. Essentially the same QR course as the one proposed had been offered for several years, but with college algebra as a pre-requisite. The new version of the course was more visible in that it was being proposed as a course in the (Arkansas) state minimum core as a substitute for college algebra, and, as such, had attracted critiques in the public media (*Arkansas Democrat-Gazette* 2012; Brawner 2012). The effectiveness of the current mathematics curriculum, including algebra, had been questioned in two highly visible op-ed pieces in the *New York Times*, one by David Mumford and Sol Garfunkel (2011) and one by Andrew Hacker (2012). As was verified by many people who commented on the Hacker article, arguments in favor of QR courses as alternatives to college algebra fall victim to being interpreted as finding an easier route for algebra-phobic students. Because QR is neither well established nor well understood, and because QR courses often do not develop any specific mathematical content, the standards for acceptance within the academic community are higher than those for a course such as statistical methods that indicates some generally acceptable (now, but less so a few decades ago) mathematical content. This backdrop prompted an articulation of the analysis of the methods and content of the QR course that is reported here, the results of which provide a framework for designing QR courses.

Developing the Design Principles

The design principles that are presented below evolved over the past eight years of teaching QR courses to college students and are rooted in the author's work with Robert Orrill and Lynn Steen in the QR initiative that Orrill led during 2000-2004 (Madison and Steen 2008b). Almost all of the principles have been described in three research reports on the QR course (Dingman and Madison 2010; Madison and Dingman 2010; Boersma et al. 2011). These principles were articulated more thoroughly in light of five research-based and one experience-based sets of criteria on student learning in the analysis of the QR course at the University of Arkansas in a reverse engineering process prompted by an increased need to evaluate, justify and improve the course and its outcomes.

[6] The course was recommended narrowly but was questioned as to both its mathematical content and the ways that the success of the course would be measured. To be fair, many courses could be questioned on the latter issue, especially college algebra.

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The process of taking something apart and revealing the way it works is often an effective way to learn how to build a device or make improvements to it; this is an aspect of reverse engineering. In order to reverse engineer the QR course I identified six collections of content and process standards and research findings on how students learn in college classrooms and used them as criteria for improvements and evaluation. In brief, these collections are:

- The six core competencies for QL as articulated in the Association of American Colleges and Universities (AAC&U) QL rubric (AAC&U 2009; Boersma et al. 2011).
- The five strands of mathematical proficiency from *Adding It Up* (Kilpatrick et al. 2001). This will be referred to as *Adding It Up*.
- The eight Standards for Mathematical Practice of the Common Core State Standards for Mathematics (CCSSM 2010).
- *The 5 Elements of Effective Thinking* as articulated by Edward Burger and Michael Starbird (2012).
- Three principles from *How People Learn* (Bransford et al. 2000) as applied to successful classroom practice. This will be referred to as *How People Learn*.
- Ten principles from *Applying the Science of Learning to University Teaching and Beyond* (Halpern and Hakel 2003).

Five of these six collections are based on research on student learning, and the sixth, by Burger and Starbird, is based on years of highly successful college classroom teaching. There are other possibilities for criteria, especially if one focuses more on immediate outcomes of QR courses rather than long-term retention and instructional design, the primary issues here. Examples are QR assessments such as the Quantitative Literacy & Reasoning Assessment (2012) and the Critical Thinking Assessment Test (Stein, Haynes and Redding 2007). Another possibility is a 1994 MAA committee report that gave a list of mathematical outcomes of QR in college (MAA 1994).

Of course, the real measure of the effectiveness of a course is student learning, especially the learning for long-term retrieval and transfer. Such measures are elusive for single college courses, to say the least, and other reasons why any measures of student learning are both difficult and of limited value will become apparent as we discuss the characteristics of the QR course in question and compare those characteristics to characteristics specified or implied by the six collections of standards and research findings. In the absence of traditional content for a QR course and reliable measures of desired learning outcomes, the six collections of criteria seem a reasonable approach to developing design specifications for or evaluating a QR course. Throughout, two rather startling conclusions from a report (Halpern and Hakel 2003) of the research findings on learning for long-term retrieval and transfer should serve as motivating beacons of a QR course design, and I present them here verbatim, for emphasis:

- "But, ironically (and embarrassingly), it would be difficult to design an educational model that is more at odds with the findings of current research about human cognition than the one being used today at most colleges and universities." (p. 38)

- "There is a large amount of well-intentioned feel-good psychobabble about teaching out there that falls apart upon investigation of the validity of the supporting evidence." (p. 41)

Evolution of the QR Course

As of this writing there are two QR courses, one with college algebra as a prerequisite and one without that prerequisite. The resolution of the relationship between these courses will take a few semesters, but both have the characteristics and philosophies discussed here. Consequently, "the QR course" will refer to either. First offered experimentally in fall 2004, the QR course has been offered each semester since. At present, the enrollment is approximately 600 students per year, mostly majors in the arts, humanities and social sciences. The course is taught in sections of 20-30 students in interactive classroom environments with tables for four, a document projector, and Internet access. The only textbook is the third edition of *Case Studies for Quantitative Reasoning* (referred to as the *Casebook*) (Madison et al. 2012) that evolved from duplicated notes and two earlier editions. The course was expanded and enhanced through the support of the National Science Foundation (DUE-0715039) from 2007 to 2012. Typically, the class meets twice weekly for 75-80 minutes throughout a semester. The *Casebook* has 30 case studies of media articles, consisting of an article, warm-up exercises, and study questions on the article. The topics of the case studies are sorted into six sections: 1) using numbers and quantities; 2) percent and percent change; 3) measurement and indices; 4) linear and exponential growth; 5) graphical interpretation and production; and 6) counting, probability, odds, and risk. A typical class meeting begins with students presenting or discussing at tables media articles they have found and brought to class that contain quantitative information. This feature has been referred to as News-of-the-Day, and students are sometimes awarded credits for presenting articles. There is usually a homework assignment of warm-up exercises, but the core activity is addressing the study questions, which probe the quantitative content of the article being discussed. Often, students address the study questions in groups of 3-4 at a single table. Quizzes and tests consist of exercises similar to the warm-up exercises and study questions on one or two articles new to the students. Mathematics is developed or reviewed as needed, when needed. For example, the sum of a geometric series is developed when needed for compounding interest or exploring installment savings or purchasing.

The success rate (grade of A, B, or C) for the course is over 80%, significantly higher than other introductory mathematics courses. The higher success rate is partly due to the prominent role of daily homework in the course but likely also due to the students' heightened interest in the subject matter. Student evaluations of the course have been favorable, and it has received high marks from faculty advisors in departments whose students enroll in the course. Pre- and post-tests were used in 2007-2008 to compare learning in this course with that in two other similar courses (see Table 1 for some summary results), and pre- and post-tests for an attitude survey were administered to the same populations. Although the results were not dramatic, learning gains as measured by the test were larger in the QR course and attitude shifts were all in the desired direction. Former students were surveyed by email after 2-3 years to see if they continued to

http://scholarcommons.usf.edu/numeracy/vol7/iss2/art3
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practice QR in looking at media articles[7]. The response rate was very low (42/300), but about half reported that they continued to practice QR; about 2/3 responded that their confidence in their QR ability had increased; and about ¾ reported that they now believed QR to be more important to them. Various effects of the course, e.g., on productive disposition, are currently under investigation.

Table 1
Comparative pre-test and post-test results

Fall 2007 – 15 multiple-choice items. Three different courses			
Course	**Number of Students**	**Number of Items with significant increase in mean scores (p<0.05)**	**Number of items with significant increase in mean scores (p<0.1)**
Survey of Calculus	106	6	9
For All Practical Purposes	77	6	7
QR	96	9	10

Spring 2008 – 17 multiple-choice items. Two different courses			
Course	**Number of Students**	**Number of Items with significant increase in mean scores (p<0.05)**	**Number of items with significant increase in mean scores (p<0.1)**
For All Practical Purposes	83	5	6
QR	95	5	9

Writing and critical reading have been important all along in responding to study questions. In fact, 26 of the 30 case studies have questions that require communication, including writing, and all 30 require interpretation, usually interpreting quantitative information given in words so it can be represented in another form, usually a function or an equation. See Table 2 below for the competency requirements of the case studies in the *Casebook* that are given in full on the website[8] that supports the *Casebook*.

Table 2.
Prevalence of competencies in questions and cases

Competency	Percent of Study Questions	Percent of Case Studies
Interpretation	67	100
Representation	30	73
Calculation	48	90
Analysis/synthesis	35	90
Assumption	7	40
Communication	38	87

Over the past three years a significant writing component has been added to a few sections of the course. The results of that and the belief that writing is important to

[7] An important outcome of QR courses is development of a QR habit of mind that would be expected to continue beyond the course and beyond school. Assessment of such a habit of mind remains to be developed and demonstrated. See Boersma and Klyve (2013).

[8] http://www.cwu.edu/~boersmas/QRCW/mappingtesting/index.html

improved QR prompted adding a significant formal writing requirement. The writing requirement, added in consultation with English composition program,[9] adds to the rigor of the course as well as to the difficulty of teaching and assessment. Part of the reason for the writing requirement is to maintain the level of rigor and to protect against the course degenerating to the methods contained therein. The more important reason for adding writing is that writing strengthens quantitative reasoning (Madison 2012; Grawe and Rutz 2009) and increases the metacognitive skills of the students. Because the course requires instructors not only familiar with using case studies in a collaborative learning classroom but also with instruction and assessment in writing, the preparation of instructors for the QR course will be expanded to include writing.

Two challenges that have not been solved are:

- What contextual examples should be generalized and abstracted? The power of mathematics is in abstraction and generalization, and students should not only see this power when it is needed but should combine results of contextual examples with abstractions to increase the long-term retrieval and transfer (Halpern and Hakel 2003; *How People Learn* 2000).
- One of the research findings (*How People Learn* 2000: 16) about developing competence in an area of inquiry is to "understand facts and ideas in the context of a conceptual framework." What are the conceptual frameworks for a QR course, or, more generally, for QR?

Guidance and Boundaries for this Paper

The multiple, complex, and interrelated lists of criteria and principles needed here prompt me to offer some guidance to the reader and place some boundaries on the following discussion. First, the six lists of criteria measures will be articulated more fully than the abbreviated list above. Second, the design principles of the QR course will be listed and discussed both from the point of view of how they influence and are reflected in the QR course and how some of the criteria measures support the principles. Third, the criteria measures will each be discussed in light of how they are reflected in the QR course. Obviously, the six lists of criteria measures overlap and have numerous connections. Comparisons among the six sets of criteria will be minimal here to avoid distractions from our primary purpose of supporting the design principles by noting their alignment with the sets of criteria.

Criteria Measures

How the QR course fares with respect to the six sets of criteria described briefly above is discussed below. First, the criteria are given in more detail. The first set of criteria, the core proficiencies for QR as developed by AAC&U and adapted by Boersma et al.

[9] Paired sections of the QR course and a composition course were tried, but students did not find an English and mathematics course for six semester hours very attractive. Having a composition instructor alongside a mathematics instructor in a writing intensive section of QR was far more appealing to students, but too labor intensive for staffing.

(2011), is the only set of the six criteria measures that was developed with QR in mind, so this set is listed first.

AAC&U QL Rubric and an Adaptation

In 2009, AAC&U published fifteen rubrics as products of its Valid Assessment of Learning in Undergraduate Education (VALUE) project. One of those fifteen was the Quantitative Literacy rubric.[10] According to AAC&U, "the rubrics are intended for institutional-level use in evaluating and discussing student learning, not for grading." The author and colleagues (Boersma et al. 2011) adapted the AAC&U VALUE QL rubric to one to assess individual student work. The result was the Quantitative Literacy Assessment Rubric (QLAR).[11] Like the VALUE rubric, QLAR has six core competencies that are required for responses to QR prompts: interpretation, representation, calculation, analysis/synthesis,[12] assumption, and communication. These are described as follows:

1. *Interpretation*: Ability to glean and explain mathematical information presented in various forms (e.g., equations, graphs, diagrams, tables, words).
2. *Representation*: Ability to convert information from one mathematical form (e.g., equations, graphs, diagrams, tables, words) into another.
3. *Calculation*: Ability to perform arithmetical and mathematical calculations.
4. *Analysis/Synthesis*: Ability to make and draw conclusions based on quantitative analysis.
5. *Assumptions*: Ability to make and evaluate important assumptions in estimation, modeling, and data analysis.
6. *Communication*: Ability to explain thoughts and processes in terms of what evidence is used, how it is organized, presented, and contextualized.

Two of the six – interpretation and communication – involve critical reading and writing (or speaking). In fact, all but calculation can involve non-quantitative communication.

The next two sets of criteria are descriptions of mathematical proficiency (for K-12, but clearly more broadly applicable) that were developed by groups of mathematicians and mathematical educators and have bases in research on teaching and learning mathematics.

Mathematical Proficiency from Adding It Up

Adding It Up is a 2001 report of the Mathematics Learning Study Committee of the National Research Council that summarizes research results on mathematics learning from pre-kindergarten through grade 8. The model of mathematical proficiency articulated in *Adding It Up* consists of five intertwined strands that are described as follows.

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[10] See http://www.aacu.org/value/rubrics/index_p.cfm,

[11] See http://www.cwu.edu/~boersmas/QRCW/Casebook/QLAR.pdf.

[12] This was application/analysis in the QL VALUE rubric.

1. *Conceptual understanding*: Comprehension of mathematical concepts, operations and relations.
2. *Procedural fluency*: Skill in carrying out procedures flexibly, accurately, efficiently, and appropriately.
3. *Strategic competence*: Ability to formulate, represent, and solve mathematical problems.
4. *Adaptive reasoning*: Capacity for logical thought, reflection, explanation, and justification.
5. *Productive disposition*: Habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence in one's own efficacy.

The Standards of Mathematical Practice of the Common Core State Standards

The Common Core State Standards' Standards for Mathematical Practice describe varieties of expertise that mathematics educators at all levels should seek to develop in their students (CCSSM 2010). These practices rest on important "processes and proficiencies" with longstanding importance in mathematics education. The first of these are the National Council of Teachers of Mathematics (NCTM 2000) process standards of problem solving, reasoning and proof, communication, representation, and connections. The second consists of the strands of mathematical proficiency from *Adding It Up* as described above. The eight practice standards are below, each with a one-sentence description. The full descriptions of the standards are at the Common Core State Standards for Mathematics website.[13] The eight practice standards will be referred to as CCSSM # where # is 1-8.

1. *Make sense of problems and persevere in solving them:* Mathematically proficient students start by explaining to themselves the meaning of a problem and looking for entry points to its solution.
2. *Reason abstractly and quantitatively:* Mathematically proficient students make sense of quantities and their relationships in problem situations.
3. *Construct viable arguments and critique the reasoning of others:* Mathematically proficient students understand and use stated assumptions, definitions, and previously established results in constructing arguments.
4. *Model with mathematics:* Mathematically proficient students can apply the mathematics they know to solve problems arising in everyday life, society, and the workplace.
5. *Use appropriate tools strategically:* Mathematically proficient students consider the available tools when solving a mathematical problem.
6. *Attend to precision:* Mathematically proficient students try to communicate precisely to others.

[13] http://www.corestandards.org/assets/CCSSI_Math%20Standards.pdf

http://scholarcommons.usf.edu/numeracy/vol7/iss2/art3
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7. *Look for and make use of structure:* Mathematically proficient students look closely to discern a pattern or structure.
8. *Look for and express regularity in repeated reasoning:* Mathematically proficient students notice if calculations are repeated, and look both for general methods and for shortcuts.

The 5 Elements of Effective Thinking

The fourth set of criteria is documented largely with anecdotes from the classrooms of the book's two authors, Edward Burger and Michael Starbird, both notable award-winning collegiate mathematics faculty members. Although the title of the book (Burger and Starbird 2012) is *5 Elements*, there are four core building blocks of effective thinking; the fifth element, change, is an expected outcome of applying the first four. The authors use the five classical elements that were once believed to be the essential parts of nature and matter – earth, fire, air, and water, plus the quintessential heavenly element aether. Contrary to what was believed about aether (that it was incapable of change), Burger and Starbird have change as their fifth and quintessential element. Briefly, these four building blocks of effective thinking are (p. 6):

- *Earth* – Understand deeply. Don't face complex issues head-on; first understand simple ideas deeply. Clear the clutter and expose what is really important.
- *Fire* – Ignite insights by making mistakes. Fail to succeed. Intentionally get it wrong to inevitably get it more right. Mistakes are great teachers – they highlight unforeseen opportunities and holes in your thinking.
- *Air* – Raise questions. Constantly create questions to clarify and extend your understanding. What's the real question? Working on the wrong question can waste a lifetime. Be your own Socrates.
- *Water* – Follow the flow of ideas. Look back to see where ideas came from and then look ahead to see where the ideas may lead. A new idea is a beginning, not an end.

Research Findings from How People Learn

Quantitative reasoning has become an indispensable skill for 21st century US residents. In *How People Learn* (2000: 4-5), the situation is summarized as follows:

> In the early part of the twentieth century education focused on the acquisition of literacy skills: simple reading, writing, and calculating. It was not the general rule for educational system to train people to think and read critically, to express themselves clearly and persuasively, to solve complex problems in science and mathematics. Now, at the end of the century, these aspects of high literacy are required of almost everyone in order to successfully negotiate the complexities of contemporary life. The skill demands for work have increased dramatically, as has the need for organization and workers to change in response to competitive workplace pressures. Thoughtful participation in the democratic process has also become increasingly complicated, as the focus of attention has shifted from local to national and global concerns.

The expanded edition of *How People Learn* represents reports on the work of two National Research Council committees, both published in 1999, one that summarized research developments in the science of learning, and one that summarized research findings on linking learning research to classroom practices. The expanded volume, published in 2000, begins with three key findings on how students learn. These findings have strong implications for teaching and are connected to our practices in the QR course as listed below (numerals indicating findings; *T* indicating implication for teaching).

> 1. Students come to the classroom with preconceptions about how the world works. If their initial understanding is not engaged, they may fail to grasp the new concepts and information that they are taught, or they may learn them for purposes of a test but revert to their preconceptions outside the classroom.
>
> 1T. Teachers must draw out and work with preexisting understandings that their students bring to them.
>
> 2. To develop competence in an area of inquiry, students must: (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in the context of a conceptual framework, and (c) organize knowledge in ways that facilitate retrieval and application.
>
> 2T. Teachers must teach some subject matter in depth, providing many examples in which the same concept is at work and providing a firm foundation of factual knowledge.
>
> 3. A "metacognitive" approach to instruction can help students learn to take control of their own learning by defining learning goals and monitoring their progress in achieving them.
>
> 3T. The teaching of metacognitive skills should be integrated into the curriculum in a variety of subject areas.

Principles from Applying the Science of Learning to the University and Beyond

What can research on human learning tell us about how to best conduct classes in college (or in any adult education setting) to teach for long-term retention and transfer? About a dozen years ago 30 experts from different areas of the learning sciences met to answer this question. As reported by Halpern and Hakel (2003), these experts identified ten "basic laboratory-tested" principles drawn from what is known about human learning. They follow below and will be referred to as Halpern and Hakel # with # being 1-10.

1. The single most important variable in promoting long-term retention and transfer is "practice at retrieval."
2. Varying the conditions under which learning takes place makes learning harder for learners but results in better learning.
3. Learning is generally enhanced when learners are required to take information that is presented in one format and "re-represent" it in an alternate format.
4. What and how much is learned in any situation depends heavily on prior knowledge and experience.
5. Learning is influenced by both our students' and our own epistemologies.

6. Experience alone is a poor teacher. Too few examples can situate learning. Many learners don't know the quality of their comprehension and need systematic and corrective feedback.
7. Lectures work well for learning assessed with recognition tests, but work badly for understanding.
8. The act of remembering itself influences what learners will and will not remember in the future. Asking learners to recall particular pieces of information (as on a test) that have been taught often leads to "selective forgetting" of related information that they were not asked to recall.
9. Less is more, especially when we think about long-term retention and transfer. Restricted content is better.
10. What learners do determines what and how much is learned, how well it will be remembered, and the conditions under which it will be recalled.

Design Principles for the QR Course

As the QR course was refined and expanded over the past eight years, some principles have evolved and been articulated in composing curricular materials and in conducting the QR classes. Some of these are strongly influenced by the circumstances of having a one-semester QR course with no continuing formal education in QR. These ten principles are articulated and discussed in the following with references to the six sets of criteria.

1. Provide a venue for continued practice beyond the course (and beyond school). Quantitative reasoning is a habit of mind, and habits are developed by practice. Especially because the QR course is for only one semester, extending the practice of QR beyond the course is critical for long-term recall and transfer. As noted in Halpern and Hakel 8, the act of remembering influences what learners will and will not remember in the future. The venue for continued practice for the QR course is media articles with quantitative content. The course utilizes case studies of media articles as the focus of study; the *Casebook* for the course consists of 30 such case studies. Media articles similar to the ones discussed in the course are now and will continue to be part of the everyday world of the students. There are several examples of successful application in professional education in the US of using problem-based case studies that prepare one for professional practice, even using the word, practice. Among these are case studies in education, medicine, law, architecture, social work, and business. Quantitative reasoning is analogous to a lifelong profession, as effective quantitative reasoning will be needed for informed performance as citizens and for personal prosperity. The QR course moves students toward developing their own habits of analysis of media articles, taking charge of their learning as promoted by principles from *How People Learn* and by Burger and Starbird (2012). In one of the activities in the QR course, students develop study questions about articles they bring to class, possibly as a News-of-the-Day contribution. Study questions, like those in the *Casebook*, can aim at, for examples, clarification of quantitative content, checking of quantitative assertions, or extending the quantitative conclusions. The variety is so extensive as to defy definition. This encourages the use of questioning to increase understanding, the element of air by Burger and Starbird (2012).

2. Keep the material relevant to students' everyday contemporary world. According to John Dewey, "School should be less about preparation for life and more about life itself." Connecting classroom learning to the everyday contemporary world not only can enhance learning at the time of study in the classroom but can lead students to adapt their classroom learning to the changing environment of everyday life. As noted in *How People Learn* (2000: 73), "The ultimate goal of schooling is to help students transfer what they have learned in school to everyday settings of home, community, and workplace." The variety of media articles and contexts in non-school environments in the QR course regularly requires adapting thinking in one context to another context. Again following *How People Learn* (2000: 73), "Since these environments change rapidly, it is also important to explore ways to help students develop the characteristics of adaptive expertise." Adaptive reasoning is one of the five strands of mathematical proficiency from *Adding It Up*.

Another of the strands of mathematical proficiency is productive disposition, a double edged proficiency depending on students seeing that mathematics (or QR) is sensible, useful, and worthwhile, coupled with a belief in their ability to understand and use it. Keeping the material relevant to the students' lives aims directly at half of this proficiency.

For various reasons, subject matter should be fresh and authentic. Even older[14] articles can be related to the present, as in Burger and Starbird's looking forward and backward. For example, a 2003 article on a political debate about how to measure the budget deficit (nominal dollars, constant dollars, or percent of GDP) easily relates to the current continuing discussion of deficits and national debt. Or a 2001 opinion piece about the economics of increasing the fuel efficiency of automobiles is analogous to the economics of choosing between a hybrid version and a gasoline version of a type of automobile.

Over the decade of developing the QR course, paper copies of newspapers and magazines have continued to give way to online sources, and online sources are available via numerous personal technologies. The shifting of sources and methods of delivery have changed the way students access media articles and has increased the variety (and uncertain reliability) of articles, adding importance to the question of evaluation of the information reported.

There are potential problems with learning in contexts. As stated in *How People Learn* (2000: 77), "Simply learning to perform procedures and learning in a single context, does not promote flexible transfer," leading to design principle 3.

3. Use multiple contexts to practice quantitative reasoning. According to Halpern and Hakel (2002; 2003), "The purpose of formal education is transfer" (p. 38 in 2003). Halpern and Hakel go on to identify retrieval in multiple contexts as one of the most basic principles to enhancing long-term retention and transfer of learning, and that spaced, not massed, practice at retrieval is best. In a one-semester QR course, significant spacing of retrieval is not possible. Consequently, there is more need for continued practice at retrieval beyond the course. With multiple contexts, students are more likely to abstract the relevant features of concepts and develop a more-flexible representation of knowledge, whereas instruction based on single contexts may lead to situated learning.

[14] a few years to an 18-year-old!

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Contextual situations need to be abstracted and generalized, which is closely related to principle 4.

4. Promote appreciation of arithmetical precision and the power of mathematical concepts and processes. This fourth principle is difficult to apply in a QR course that is based on analyzing contextual situations, especially so when contextual circumstances dictate degrees of reasonable accuracy. The CCSSM practice standard, attend to precision, has to be interpreted appropriately here because attending to precision is influenced by context.

Developing mathematical formulas and models when they are needed points to reasons why the work is worthwhile. As stated in *How People Learn* (2000: 139), "An alternative to simply progressing through a series of exercises that derive from a scope and sequence chart is to expose students to the major features of a subject domain as they arise naturally in problem situations. … Ideas are best introduced when students see a need or a reason for their use – this helps them see relevant uses of knowledge to make sense of what they have learned." In the QR course, an example of this just-in-time-as-needed development is summing of a geometric series when the length of the sum has exceeded calculator capability.

Much of the power in mathematics is in abstraction and generalization, and this is a motivation for the eight CCSSM practice standards. In fact, it is stressed in CCSSM 7, look for and make use of structure, and CCSSM 8, look for and express regularity in repeated reasoning. Abstraction and generalization trouble many students, especially those who are somewhat math-phobic. By seeing uses of and reasons for abstraction and generalization, their difficulties can be reduced. However, multiple uses of similar processes in different contexts give rise to the need for abstraction and generalization, which can organize information to facilitate retrieval.

5. Help students to structure their quantitative reasoning in resolving problematic situations, including ample doses of critical reading and writing. One way to help students structure their quantitative reasoning is to use the core competencies of interpretation, representation, calculation, analysis/synthesis, assumptions, and communication (AAC&U 2010; Boersma et al. 2011). If students understand that they need some or all of these six competencies to address a QR situation, then they can organize their responses accordingly and produce a full response. Curricular materials and questioning prompts should be composed in consideration of which competencies are needed for the proper responses. For example, if the student should communicate a response in writing, the prompt should so indicate. Requiring students to write responses promotes clearer thinking and deeper understanding, and writing requirements should progress from sentences to paragraphs to multi-page reports. Students in one of the sections of the QR course in Spring 2012 commented about combining writing and quantitative reasoning (called math by many students). One wrote, "… instead of just working a problem and moving on, I had to evaluate the process and determine how to explain the process in words." Another was more explicit, showing some negativism toward mathematics, "Math is virtually useless without proper communication of its meaning." College faculty who were participants at a 2012 Conference on Interdisciplinary Teaching and Learning at Michigan State University discussed why writing was an effective vehicle for assessing interdisciplinary learning. As one participant stated, "writing manifests thinking." Students need to get writing structure down in order to progress intellectually and communicate that progress to others. Reflective writing can reveal how well students are integrating ideas from different sources or disciplines. One participant quoted from Richard Guindon's 1989 *San Francisco Chronicle* cartoon: "Writing is nature's way of showing you how sloppy your thinking is."

The QR course now has multiple (currently, four) significant writing assignments (200-500 words) with peer review of the first draft by 2-3 classmates. This moves students toward taking charge of their learning by not only having them judge their own writing but also judge each other's writing. Of course, writing prompts are aimed at having quantitative reasoning as a significant part of an appropriate response.

6. Encourage on-the-fly calculations and estimations. If students are able to quickly assess the validity of a quantitative assertion or mentally compute a numerical result, then they will be more able to practice QR in many aspects of their daily lives. This increased practice will strengthen their analysis and calculation, thereby building formidable QR skills. This practice is one of the places where one can develop automaticity of skills. Facility with mental arithmetic and estimation allows one to "function effectively without being overwhelmed by attentional requirements" (*How People Learn* 2000: 139). This skill is part of the *Adding It Up* strand of procedural fluency, i.e. ability to carry out procedures flexibly, accurately, efficiently, and appropriately. This practice is also part of CCSSM 6, attend to precision**.** Knowing the degree of accuracy needed to understand a quantitative situation allows for simplification that promotes mental calculations. Further, knowing the constraints that contexts place on precision not only allows simplification but also reflection on the contextual circumstances.

7. Increase students' supplies of quantitative benchmarks. Personal quantitative benchmarks are critical for understanding quantities and being able to determine reasonableness of quantitative assertions or numerical answers to questions. Having known benchmarks to measure results of reasoning can help learners know the quality of their comprehension. Comprehending quantities, especially very large or very small ones, can be aided by expressing them in personally understandable units. One's personally understandable units depend heavily on one's supply of personal quantitative benchmarks. Joel Best (2008: 7) points to the importance of statistical benchmarks in spotting dubious data. "Having a small store of factual knowledge prepares us to think critically about statistics. Just a little bit of knowledge – a few basic numbers and one important rule of thumb – offers a framework, enough basic information to let us begin to spot questionable figures." Best gives four benchmarks that go a long way in understanding US social statistics. These are the US population (approx. 300 million), the annual birth rate (approx. 4 million), the annual death rate (approx. 2.4 million), and the approximate fractions of the population of major ethnic or racial groups.

At the 2012 Quantitative Reasoning Symposium in Mathematics in Savannah, GA, Gail Jones (North Carolina State University) began a presentation by showing a highly magnified image of part of a familiar biological entity and began showing successive images with less magnification (Jones 2012). She asked audience members to take note of the point at which they were able to identify the entity. Namely, at what magnification was the entity understandable—i.e., when could you recognize what it was? (In my case, it was at either the penultimate image or the final image that I was able to see that the entity was a common ant.) Understanding the whole better than parts of the whole is an inversion of the problem given students in a think-aloud session, namely, express $1.2 trillion in terms that make it understandable to you. One reasonable solution was to note that $1.2 trillion is enough to purchase every person in the states of Arkansas and Kentucky a house costing approximately $150,000 each. Note that in the ant visualization example, one understands by seeing the whole, or nearly whole, animal as opposed to small pieces magnified. In the $1.2-trillion example one understands by breaking the large entity into smaller pieces. Of course, experts on ants might recognize the ant at higher magnifications of its parts, and managers of large money accounts might not need to re-express the $1.2 trillion.

As students use quantitative benchmarks, their supply grows, as does their understanding of quantities. Broadening the possibilities of comprehending quantities is consistent with Burger and Starbird's understanding deeply, clearing the clutter of meaningless measurements.

8. Encourage students to use technology to enhance and expedite understanding. Technology, including personal devices, is omnipresent in the everyday lives of QR students, so it is leveraged in service of understanding. As examples, students are encouraged to use technology for calculations exceeding on-the-fly abilities, to graph functions on graphing calculators, and to use spreadsheets for repetitive calculations. In QR class sections, a statistic or another piece of information is often needed. Students use smart phones or sometimes rely on one designated student as "Googler of the Day." How personal technologies affect learning is not clear; research projects to determine answers will have difficulty keeping pace with the changing technologies. However, since these technologies are certain to be a part of students' future everyday lives, they are a part of the QR classes. As stated in the CCSSM 5, use appropriate tools strategically.

9. Allow student interests to emerge. As reported in *How People Learn* (2000: 77)**,** "Students are motivated to spend time needed to learn complex problems that they find interesting. Opportunities to use knowledge to create products and benefits for others are particularly motivating for students." The QR class addresses student interests by way of students finding media articles with quantitative content, bringing them to class and explaining them to the class or formulating questions (like the study questions in the *Casebook*) that they can or cannot answer. Students who are interested in baseball may bring a comparison of the statistics of Albert Pujols and Henry Aaron. Students who are interested in the military may bring a statistical analysis of military budgets of different countries. Increasing student interest encourages student-generated questioning, one of the four elements of effective thinking.

10. Provide interactive classroom environment. Inquiry-based learning is emphasized in the QR classes, and students often work in groups of 3-4. Social interaction is important as a motivation and as a vehicle for developing understanding. According to Halpern and Hakel 10, "What learners do determines what and how much is learned, how well it will be remembered, and the conditions under which it will be recalled" (p. 41). Inquiry-based learning and interactive classrooms are fundamental in the elements of effective thinking by Burger and Starbird. Understanding deeply, making mistakes, asking questions, and looking forward and backward are common components of interactive classrooms.

How Criteria Are Reflected in the QR Course

The discussion above indicates how the QR course design principles are supported by some of the criteria in the six sets. Below, each of the six sets is discussed as to how it is reflected in and influences the QR course.

Core Competencies and the QR Course

The QR core competencies – interpretation, representation, calculation, analysis/ synthesis, assumption, and communication – serve multiple purposes. They provide the basis for rubrics to assess student work; they offer ways to structure students' understandings; they are reminders of what we are seeking to develop in curricular materials and assessments. There are 268 study questions in the 30 case studies in the 3rd edition of the *Casebook*. Although most (1st and 2nd editions) of the *Casebook* was written before the QL core competencies were articulated, the changes for the 3rd edition focused on incorporating what was learned from adapting the AAC&U rubric to assess student work (Boersma et al. 2011). The competencies to assess with study questions were classified, and the rubric for scoring student work was incorporated in the introduction of the *Casebook*. The proportions of the 30 case studies and the 268 study questions that require each of the six competencies are shown in Table 2.

An example of a case study (Boersma et al. 2011, p. 7) where the study questions require all six competencies is an op-ed article that argues that forcing fuel efficiency on consumers does not work. The argument is based on the economics of buyers, namely making assertions that the $1466 extra for a more fuel-efficient pick-up truck is a bad investment. Study questions focus on testing the economic assertions made in the article. Interpretation, representation, calculation, analysis/synthesis, and communication are required for answers to several of the questions, and assumptions need to be made about the cost of gasoline and the number of miles driven annually.

Strands from Adding It Up *and the QR Course*

Although the five strands – conceptual understanding, procedural fluency, adaptive reasoning, strategic competence, and productive disposition - were part of the basis for the CCSSM standards for mathematical practice, the articulation of these five as above is more succinct and identifies what appears to be a critical proficiency for many of our students – productive disposition.

The core competencies in QLAR are manifestations of these and related proficiencies. In work with QR students, productive disposition seems to be critically important for practicing QR in contemporary society, and all six core competencies seem to depend on productive disposition. As reported in describing the experience in developing the QRCW course (Dingman and Madison 2010), the students are initially (on average) negative about their view of and experiences in mathematics, both in its utility to them and their abilities to use it. Improving this productive disposition is paramount in efforts to help the students toward stronger QR.

Interpretation in QLAR depends more on conceptual understanding; representation depends more on both conceptual understanding and strategic competence; calculation is strongly related to procedural fluency; analysis/synthesis depends on strategic competence and adaptive reasoning as does assumptions; and communication is closest to

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adaptive reasoning. Reflection, explanation, and justification in adaptive reasoning play major roles in resolving contemporary QR situations.

CCSSM Practice Standards and the QR Course

Practice standards 1, 2, 3, and 4 are dominant in contemporary QR as addressed in the QR course. Making sense of problems; modeling with mathematics or statistics; reasoning quantitatively; and drawing, supporting and communicating conclusions are integral parts of QR. Critiquing the reasoning of others is often the entry point into a QR situations as they appear in public media articles. Practice standards 5–8 are less central to QR. There is attention to precision (CCSSM 6), but most attention focuses on the precision needed or possible in resolving the QR situation. Certainly the use of appropriate units is crucial in QR and somewhat unusual as noted above in QR course design principle 7. Tools (CCSSM 5) for our QR students include calculators (and sometimes, spreadsheets) and quantitative benchmarks for detecting reasonableness of answers. CCSSM standards 7 and 8 are less obvious in resolving QR situations.

5 Elements *and the QR Course*

Burger and Starbird's five elements are aimed at students (and others) taking control of their own learning, as in *How People Learn* #3. Although there are anecdotes from their classrooms that illustrate the five elements in action, the real message is to the learner-thinker.

Earth. Burger and Starbird (2012) get at teaching in depth of *How People Learn* #2 in several ways. While giving advice on how to understand deeply, they say, "Sweat the small stuff" (p. 25). They note that when studying some complex issue, instead of attacking it in its entirety, find one small element of it and solve that part completely.

Deep understanding at first blush seems like something that one cannot achieve in a one-semester QR course. In fact, as mathematics faculty tend to judge mathematics courses, they are likely to consider a QR course such as the one discussed here as not promoting or requiring deep understanding. They likely are judging on the depth of understanding of the mathematical concepts and not on the sophisticated and habitual use of rather elementary mathematical concepts to understand quantitative situations. Deep understanding of ratios, proportions, rates of change, and graphical representations are not the aim of most college mathematics courses, but they are among the aims of the QR course. Clearing the clutter in analyzing a quantitative argument in a media article and getting to the gist is a critical first step in understanding. This requirement of depth in understanding contextual situations is one of the major distinctions of a quality QR course.

Fire. Mistakes can be great teachers, but QR students initially are not inclined to venture opinions or propose solutions. In the QR class every mistake is a learning opportunity. This is a major issue in the student presentations of News-of-the-Day articles. Many students are reluctant to stand up in front of a class (and the teacher) and demonstrate their quantitative reasoning, which often contains errors. Reluctance can be defused by handling mistakes carefully and straightforwardly because everyone makes mistakes, and everyone can learn from them. One of the most common mistakes occurs in backing up a percentage change. Canonically, one knows the value of a quantity now and a percent change from some point in the past and wants to find the value at the point in the past.

About ¾ of the students entering the QR course answer this incorrectly, and these same mistakes persist throughout the semester. This canonical mistake in a News-of-the-Day presentation provides an opportunity to point out how common this is and urge remembering the correct way. By semester's end, about half the students still make this mistake.

Air. Raising questions by QR students is initially stymied by the same attitudes that keep them from venturing solutions or opinions. Their experiences in traditional mathematics and statistics courses point them toward responding to questions that have definite and often unique answers. The core material in the *Casebook* consists of study questions on media articles that serve as examples of questioning that they should employ in QR in everyday life beyond the course. Many of these questions do not have clearly defined answers, which can be frustrating to students not accustomed to such situations. However, the vague nature of some situations invites student questioning, and QR instructors model such questioning, especially in regard to News-of-the-Day articles being presented by students.

Water. News media articles invite looking backward at the origins of the information and forward to where it might lead. Further, the ideas developed in exploring and understanding one media article are often applicable to other articles. So the flow of ideas has two channels, one regarding a particular context of one article and one that takes the understanding of one article and utilizes it in understanding other articles, perhaps even in very different contexts. As an example, one of the QR case studies aims at understanding inflation by way of looking at the cost of a product (in this case, the Chuck Taylor All Star canvas shoe) that has remained essentially the same over the past half century. This is a very real situation as it is often the case that some student in a QR class may be wearing the All Star shoe. One has the chance to think backward to the 1950s and forward to see what the shoe might cost in 20 years. And the ideas here easily extend to more complex situations, say, considering arguments about how to measure federal revenues, spending, and deficits or surpluses.

How People Learn *and the QR Course*

The three principles, in brief, are: (1 and 1T) engaging preexisting understandings; (2 and 2T) factual knowledge, conceptual framework, and facilitating retrieval; and (3 and 3T) metacognition. How does the QR course respond to these principles?

1 and 1T. Some of the preconceptions that students bring to the QR course are molded by their experiences in previous mathematics classes (Dingman and Madison 2010). They are accustomed to courses with structured lectures, template problems, textbooks with numerous example exercises, and homework that utilizes the method of the day to solve problems that have one and only one solution. Because this is very different from the everyday QR challenges these students will face, the QR course and "textbook" are different. The absence of multiple template problems frustrates some students, illustrating that varying conditions of learning makes it more difficult for students but results in more learning. Students are also not accustomed to seeing mathematics, especially algebra, as a tool for understanding media articles, and this is the central purpose of the QR course. Students usually are not prepared to make the connections between the QR circumstances and their previous learning in arithmetic and algebra. They do not see the utility of their

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arithmetic and algebra in resolving the QR issues, and so these connections are made within the QR class often serving to review the algebra, in particular.

2 and 2T. Presentation of an organized set of facts is not specified in the QR course. The knowledge that students are to apply consists of mathematics and statistics learned in school or early college. Beyond that, they need to understand or learn the basics of various contexts – political, social, economic, etc. – of the media articles in the case studies and articles brought to class by students. One of the weaknesses (noted above) of the QR course is in developing conceptual frameworks for QR, and the absence of conceptual frameworks takes away a powerful retrieval and transfer mechanism.

3 and 3T. The one-semester QR course functions like a prelude to continuing practice beyond the course. Having students take charge of their learning is a major goal. Much of what is done is aimed at that: creating a venue for continued practice, contexts from contemporary student life, increasing the supply of personal quantitative benchmarks, asking good questions, reflective writing on answers, and being able to judge ones comprehension.

Applying the Science of Learning to the University and Beyond *and the QR Course*

What can research on human learning tell us about how to best conduct classes in college (or in any adult education setting) to teach for long-term retention and transfer? About a dozen years ago 30 experts from different areas of the learning sciences met to answer this question. As reported by Halpern and Hakel (2003), these experts identified ten "basic laboratory-tested" principles drawn from what we know about human learning. They follow below, and after each principle, connections to the QR course are given.

1. **The single most important variable in promoting long-term retention and transfer is "practice at retrieval."** Practice at retrieval within the QR course can take place with questioning in class, collaborative learning situations where one student explains to another, and responding to assessment items or homework assignments. Spaced practice is better than massed practice, so spreading concepts such as relative change versus absolute change over an entire course, in different contexts, facilitates learning for long-term transfer.

2. **Varying the conditions under which learning takes place makes learning harder for learners but results in better learning.** The absence of template problems, as noted above, is the main adherence of our QR course to this principle. Each case study is different, but there are conceptual strands that run through multiple cases. Identifying and emphasizing these strands remains one of the challenges of the course.

3. **Learning is generally enhanced when learners are required to take information that is presented in one format and "re-represent" it in an alternate format.** As noted earlier, all of the case studies and 2/3 of the study questions require interpretation (i.e., gleaning and explaining information presented in various forms) and ¾ of the cases require representation, i.e., converting information from one mathematical form to another.

4. **What and how much is learned in any situation depends heavily on prior knowledge and experience.** This principle is basically the same issue as 1 and 1T above, so the discussion there applies. In addition, all of the QR students have demonstrated modest facility with algebra, and almost all have been successful in two English composition courses.

5. **Learning is influenced by both our students' and our own epistemologies.** One of our findings about the QR students is that they are weak on productive disposition, i.e., the habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence in one's own efficacy. A principal aim of the QR course is to convince students that QR is important to them and that they are capable of making use of it in their daily lives.

6. **Experience alone is a poor teacher.** Too few examples can situate learning and deter transfer. Many learners do not know the quality of their comprehension and need systematic and corrective feedback. The use of a variety of authentic cases can point out to students the consequences of various conclusions in real-life situations. The feedback can convince students that their experiences are not conclusive and push them to consider other alternatives.

7. **Lectures work well for learning assessed with recognition tests, but work badly for understanding.** Learning via case studies as in the QR course does not rely on extensive lecturing, relying more on just-in-time mini-lectures to address a needed concept or method. Assessments are not recognition tests and the QR habits rely more on questioning, relationships, and elementary arithmetic than on algorithms and formulas.

8. **The act of remembering itself influences what learners will and will not remember in the future.** Asking learners to recall particular pieces of information (as on a test) that have been taught often leads to "selective forgetting" of related information that they were not asked to recall. As noted above, the QR course does not emphasize facts and processes that students need to remember. Identifying a few conceptual frameworks that have broad application would alleviate the possibility of promoting "selective forgetting."

9. **Less is more, especially when we think about long-term retention and transfer. Restricted content is better.** The mathematical and statistical methods in the QR course are quite restricted but broadly applicable. Mathematical formulas or concepts are developed only if there is an immediate reason, and most of those developed have broad applications to QR.

10. **What learners do determines what and how much is learned, how well it will be remembered, and the conditions under which it will be recalled.** We keep the admonition that the mind remembers what it does in front of all our instruction. Collaborative inquiry-based learning is a major theme of the course.

Final Thoughts

The QR course was not designed with the principles listed above explicitly stated. Nor was it designed in overt consideration of any of the six sets of criteria, except perhaps the

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research results on human cognition, which were reasonably well known to the author as the course was initiated and refined by the author and colleagues S. Dingman, S. Boersma, and C. Diefenderfer over the past eight years. And looking at the result in light of the six sets of criteria has no doubt influenced forming the now-recognized ten design principles. The qualitative evidence that the design principles of the course align reasonably well with most of the principles in the six sets of criteria is a good starting point for a more rigorous evaluation of the course. The alignment is far from perfect. As noted earlier there are two unresolved alignment issues:

1. What contextual examples should be generalized and abstracted to take advantage of the power of mathematics?
2. What are the conceptual frameworks for QR?

The alignment with the QL core competencies is understandably strong since these are competencies for QR. The alignment with the five strands of mathematical proficiency is stronger than that with the practice standards of CCSSM, which are attuned more to traditional mathematics proficiency. Alignment with the *5 Elements* of Burger and Starbird (2012) seems reasonably strong, but the explication of these in their book by the authors points clearly to the personal pedagogies of the authors, so alignment here likely depends more on the implemented course. Alignment with the principles from *How People Learn* and those articulated by Halpern and Hakel (2003) is probably the strongest of all, and this might be surprising except for the fact noted above that I knew of these principles before I began designing and teaching the QR course. There are sprinkles of other evaluative evidence, some of it quantitative – surveys of faculty advisors, student evaluations, some pre- and post-test data, and some follow up survey data of former students. Most of the evidence appears to support the conclusion that the design of the course supports strong learning by QR students.

However there are uncertainties. One is the uncertainty of how well aligned the implemented course is with the designed course. With most of the instructors inexperienced in leading this kind of course, implementation can vary from design. The design has been reviewed rather thoroughly during the past year, and professional development programs for QR instructors are being formulated.

Until there are assessment instruments that are reliable measures of long-term retention and transfer or QR habits of mind, qualitative evidence of alignment with research-based principles that apply to QR learning will continue to be useful. These principles constitute a fairly high standard as indicated by the six sets of criteria here, and not the "well-intentioned feel-good psychobabble about teaching out there that falls apart upon investigation of the validity of the supporting evidence," as quoted from Halpern and Hakel (2003) in the introduction. Such alignment with accepted principles adds some concurrent validity to the face validity of the QR course at the University of Arkansas.

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Breakout 2

QR across the Curriculum: From Creating Assignments to Measuring Outcomes

E. Gaze

Numeracy
Advancing Education in Quantitative Literacy

Manuscript 1147

Teaching Quantitative Reasoning: A Better Context for Algebra

Eric Gaze

Teaching Quantitative Reasoning: A Better Context for Algebra

Abstract

This editorial questions the preeminence of algebra in our mathematics curriculum. The GATC (Geometry, Algebra, Trigonometry, Calculus) sequence abandons the fundamental middle school math topics necessary for quantitative literacy, while the standard super-abundance of algebra taught in the abstract fosters math phobia and supports a culturally acceptable stance that math is not relevant to everyday life. Although GATC is seen as a pipeline to STEM (Science, Technology, Engineering, Mathematics), it is a mistake to think that the objective of producing quantitatively literate citizens is at odds with creating more scientists and engineers. The goal must be to create a curriculum that addresses the quantitative reasoning needs of all students, providing meaningful engagement in mathematics that will simultaneously develop quantitative literacy and spark an interest in STEM fields. In my view, such a curriculum could be based on a foundation of proportional reasoning leading to higher-order quantitative reasoning via modeling (including algebraic reasoning and problem solving) and statistical literacy through the exploration and study of data.

Keywords

quantitative reasoning, STEM education, proportional reasoning, modeling, statistical literacy

Cover Page Footnote

Eric Gaze is President of the National Numeracy Network. A mathematician, he is the Director of the Quantitative Reasoning Program at Bowdoin College, and Lecturer in the mathematics department. Eric has been involved with developing QR curricula for over 15 years and leads workshops around the country on teaching and assessing QR.

Introduction

There has been a steady growth of QR-type courses since 1995 with Math for the Liberal Arts and Finite Math enrollments rising 63% from 195,000 students in 1995 to 318,000 students in 2010 (Table 1).[1] Meanwhile, Calculus I enrollments rose only 20% over the same period, from 250,000 to 300,000 It is worth underscoring that the two general education math courses exceeded mainstream Calculus I enrollments 318,000 to 300,000 in fall 2010.

Table 1
Conference Board of Mathematical Sciences 2010 Survey*
(Enrollments in thousands)

	1995	2000	2005	2010
Two-year colleges				
Finite Math	24	19	22	18
Liberal Arts Math	38	43	59	91
Calculus I	58	53	51	65
Four-year colleges and universities				
Finite Math	59	82	94	62
Liberal Arts Math	74	86	123	147
Calculus I	192	192	201	235

* Blair et al. 2013

Even so, *Math for Life: Crucial Ideas You Didn't Learn in School* by Jeffrey Bennett (Bennett 2012; Gaze 2012) raises the still-relevant question of why the current mathematics curriculum is so devoid of the material needed to navigate our personal worlds of finance, business, and citizenship. We in the National Numeracy Network and the QR movement are undoubtedly familiar with the rationale for the "GATC" sequence (Geometry, Algebra, Trigonometry, Calculus). It is billed as a pipeline to the STEM fields (Science, Technology, Engineering, and Mathematics) and, hence, the critical professions that drive job growth and scientific/technological innovation. Conventional wisdom dictates that calculus, in particular, holds pre-eminent status as the gateway to STEM. Fifty years ago, if you asked STEM faculty in universities and colleges for the mathematical pre-requisites for success in calculus, they undoubtedly would reply algebra, with a bit more algebra, some trig, and then more algebra. Not only does the GATC sequence completely abandon the fundamental middle school math topics necessary for quantitative literacy but this super-abundance of algebra taught in the abstract fosters math phobia and supports the *culturally acceptable* stance that math is not relevant to everyday life.

[1] Data are from the CBMS 2010 Survey of Undergraduate Mathematical Sciences Programs (Conference Board of the Mathematical Sciences). For the full report, see Blair, Kirkman, and Maxwell, 2013.

The unquestioned super-importance of algebra has been close to gospel in the mathematics education community. U.S. Secretary of Education Arne Duncan's speech April 15, 2011, to the National Council of Teachers of Mathematics (NCTM) contains the line: "Algebra is the key to success in college."[2] Educators are, however, beginning to question this bold claim. Consider NCTM President Michael Shaughnessy's message in February 2011 titled: "Endless Algebra – The Deadly Pathway from High School Mathematics to the College Mathematics"[3] This is a good example of two well-meaning advocates arriving at radically opposed positions while looking at the same data: Of the 4,012,770-member cohort of 2001 9th graders, only 1,303,050 were college-ready in fall 2005 and only 166,530 graduated with a STEM degree in the next six years (on or before May 2011). The paltry 166,530 STEM degrees (4% of the entering 9th grade cohort) led Secretary Duncan to conclude we are experiencing a *STEM crisis* and need to increase the numbers of STEM graduates by "increasing the rigor of what is taught in the classroom" (i.e., algebra). Mike Shaugnessy, on the other hand, looks at the other 3,846,240 students (96%) for whom the "tunnel of repetitive algebra" paid no dividends and sees a *QR crisis*; he asks for a better mathematical experience for these students.

Just how crowded is this tunnel of repetitive algebra? The developmental math program at two-year colleges is centered on algebra with 61% of all math enrollments at two-year schools in Fall 2010 in some flavor of algebra (Table 2). This statistic is even higher given that 30% of two-year schools have their pre-college level math programs offered outside of the math department in developmental (remedial) programs.

Table 2
Enrollments in Math Courses at Two-Year Colleges* (Enrollments in thousands)

	1990	1995	2000	2005	2010
Pre-College Level					
Pre-Algebra	45	91	87	137	226
Elementary Algebra (HS level)	262	304	292	380	428
Intermediate Algebra (HS level)	261	263	255	336	344
Pre-Calculus Level					
College Algebra	153	186	173	206	230
College Algebra + Trigonometry	18	17	16	14	11
Total	1272	1425	1347	1696	2024

* Blair et al. 2013

[2] http://www.ed.gov/news/speeches/math-teachers-nation-builders-21st-century (accessed 11 June 2012)
[3] http://www.nctm.org/about/content.aspx?id=28195 (accessed 11 June 2012)

For students enrolled in these courses, algebra is not so much the key to success in college as the barrier to entry. To continue to teach these students the standard form of algebra over and over hoping for a better result is pointless. What is needed is a better way to teach algebra. A rigorous QR course can provide just the setting by grounding algebra in real-world context. The QR community appreciates the severity of the STEM crisis and does not see addressing the QR crisis (creating quantitatively literate citizens) as being at odds with creating more scientists and engineers. In some sense, they are two sides of the same coin. The QR community seeks to create a curriculum that addresses the quantitative reasoning needs of all students, providing meaningful engagement in mathematics that will simultaneously develop quantitative literacy and spark an interest in STEM fields. NCTM President Mike Shaughnessy points out that the current "layer cake of algebra-dominated mathematics" exists solely to prepare students for calculus, and he offers four concrete alternative pathways:

1. Data analysis, combinatorics, probability and numerical trends/modeling.
2. Statistical thinking and decision making.
3. Linear algebra.
4. Multivariate applications of calculus and statistics.

Quantitative Reasoning courses can provide the necessary foundation for this mathematics curriculum, building and developing the critical middle school mathematics topics that currently are abandoned in high school but serve as the foundation for numeracy. In addition, a QR course can deepen algebraic reasoning through intentional teaching utilizing spreadsheets for data analysis and modeling.

Developing QR Curricula

My background in QR includes both teaching and assessing QR spanning the entire K-16 curriculum:

- teaching and developing a QR course for college students which has led to the writing of a QR textbook, *Thinking Quantitatively* (Gaze, in preparation),
- creating and developing the curriculum for a Masters in Numeracy Program for K-12 teachers at Alfred University (Gaze 2010),

- working as Principal Investigator on an NSF-funded TUES Type I project, *Quantitative Literacy and Reasoning Assessment* (QLRA), DUE: 1140562, 2/15/12-1/31/14.

Over the last four years I have had the opportunity to work with many partners on QR curriculum initiatives including the Carnegie Foundation's *Quantway* project, the Dana Center at UT Austin's *National Math Pathways* project, and QR curriculum development projects with the community college systems in the states of Indiana and North Carolina. These diverse projects have all led to the development of QR curricula that are remarkably consistent. There are three main content areas that are incorporated into the QR courses:

1. Proportional Reasoning
2. Probability and Statistics
3. Modeling

The course outcomes and objectives are all similar to those written by Ivy Tech Community College faculty in Indiana:

> Upon successful completion of this course the student will be expected to define problems clearly, identify relevant information, ask pertinent questions, and support conclusions using persuasive quantitative reasoning. Students will be able to:
>
> 1. Use and interpret **ratios** in all their guises: rates/percentages/decimals.
> 2. Use **proportional reasoning** in context (real world data sets), including **scale** and **similarity**.
> 3. Operate within and between different measurement scales including **unit conversion** and **dimensional analysis**.
> 4. Use **estimation**, check reasonableness of answers, and evaluate **precision** and **accuracy** of data.
> 5. Use and interpret **percentages** in various forms: **probability**, **risk**, **rates of return**, **percentiles**, and **relative frequency**.
> 6. Develop fundamental **financial literacy** including annual percentage rates, periodic rates, loans (amortization tables), retirement (annuities).
> 7. Compute, contrast, and interpret **absolute and relative change**, including margin of error.
> 8. Explore and interpret rates of change, contrasting **linear** versus **exponential growth** (simple versus compound interest).
> 9. Interpret visual representations of **data**, examine statistical arguments including sampling, **correlation and causation**.

10. Analyze real world data through **descriptive statistics** (measures of central tendency and dispersion), **normal distributions**, and **z-scores**.
11. Use **algebraic reasoning** to explore relationships between variables, including the construction and use of equations to solve problems, i.e. modeling.
12. Research and select appropriate formulas/strategies to solve real world problems. Solve a variety of application problems in the above areas.
13. Use relevant mathematical language, laws, and notations appropriately.
14. Use a scientific calculator proficiently as related to coursework.
15. Use computer technology, which may include the Internet, **spreadsheets**, or computer tutorials/simulations to enhance the course objectives.

Conclusion

The above-listed QR curriculum focuses first on the key numeracy skill set of proportional reasoning by systematically developing the concepts of unit, scale, fraction, percent, proportion, decimal, and rate around the common theme of ratio. This foundation leads to higher-order quantitative reasoning via modeling, with statistical literacy guiding the exploration and study of data. Spreadsheets offer an easy entry into modeling with computers, while at the same time developing students' algebraic reasoning.

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2014	Name:
QLRA QUANTITATIVE LITERACY & REASONING ASSESSMENT	ID: Time to complete exam:

Directions for Assessment

You may use a calculator, but few problems require exact calculations. Please have scratch paper and pencil handy. Please select the one best answer to each question.

This is designed to test your quantitative reasoning skills, which is different from traditional mathematics material. You may not be familiar with all the concepts on the exam. Do not worry if something is new to you. Read each problem carefully and do your best. The test is not corrected for guessing, so it is to your advantage to answer each question.

1. In a certain company there are 3 times as many men working as women. What is the fraction of employees that are female?

a. $\frac{1}{3}$ b. $\frac{3}{10}$ c. $\frac{2}{3}$ d. $\frac{3}{4}$ e. $\frac{1}{4}$

2. Maine lobstermen netted a record catch of 75,298,328 pounds of lobsters in 2006, which was a 5.2% increase over the previous record catch in 2004. What was the weight in pounds of the 2004 catch?

a. 79,213,841 b. 71,576,357 c. 71,122,366 d. 73,465,298 e. 71,382,815

3. There are 0.15 grams of powder in a dish. One-fifth of the powder spills out of the dish. How many grams of powder are left in the dish?

a. 0.12 b. 0.75 c. 0.30 d. 1.2 e. 0.03

4. Use the following table of 2010 exchange rates to solve the problem.

Currency	Dollars per Foreign	Foreign per Dollar
British pound	1.678	0.5958
Canadian dollar	0.7483	1.336
European euro	1.169	0.8554
Japanese yen	0.008482	117.9
Mexican peso	0.0943	10.6045

You wish to exchange 100 British pounds for Japanese yen. How many yen do you receive?

a. 0.8482 b. 0.505 c. 167.80 d. 11,790.43 e. 19,783.62

5. The age dependent population consists of the under 18 and over 64 year old populations. The age dependency ratio is computed by dividing the age dependent population by the 18-64 year old population, and multiplying by 100. In 2010 this ratio is 59.08. Which of the following sentences correctly uses the ratio?

a. The population that is age dependent is 59.08%.
b. The age dependent population is 59.08% of the population.
c. There are 59.08 people in the in the age dependent population per 100 people in the 18-64 population.

d. The percentage of the combined age dependent population that are dependent on the 18-64 population is 59.08%.
e. There are 59.08 people in the combined age dependent population per 100 people in the population.

6. A parcel of land measures 2 $^3/_5$ acres. A developer wishes to divide the land into lots for houses each measuring 1/3 of an acre. Into how many complete lots can the acres of the parcel of land be divided?

a. 2 b. 6 c. 7 d. 8 e. 11

7. The 2010 federal budget for the United States includes spending $164 billion to pay interest on the national debt. If this amount is 4.62% of the total budget, what is the total federal budget? (1 billion = 10^9, 1 trillion = 10^{12})

a. $355 billion b. $156 billion c. $7.6 trillion d. $7.6 billion e. $3.55 trillion

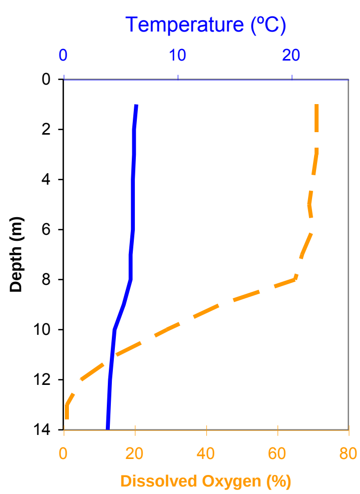
8. A married couple are calculating their federal income tax using the tax rate tables:

If Taxpayer's Income Is...		Then Estimated Taxes Are...		
Between	**But Not Over**	**Base Tax**	**+ Rate**	**Of the Amount Over**
$0	**$16,700**	**$0**	**10%**	**$0**
$16,700	**$67,900**	**$1,670.00**	**15%**	**$16,700**
$67,900	**$137,050**	**$9,350.00**	**25%**	**$67,900**
$137,050	**$208,850**	**$26,637.50**	**28%**	**$137,050**
$208,850	**$372,950**	**$46,741.50**	**33%**	**$208,850**
$372,950	**- - - - -**	**$100,894.50**	**35%**	**$372,950**

How much tax will they have to pay on their taxable income of $112,000?

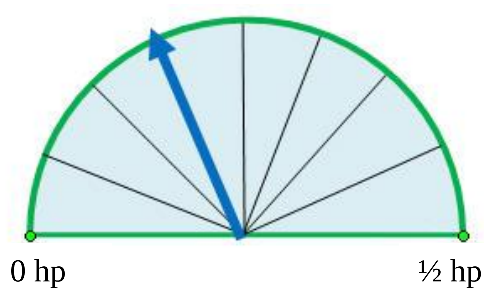
a. $28,000 b. $20,375 c. $9,350 d. $11,025 e. $37,350

9. The following graph shows temperature (solid line) and dissolved oxygen (dotted line), plotted against depth in a lake. Which of the following statements is correct?



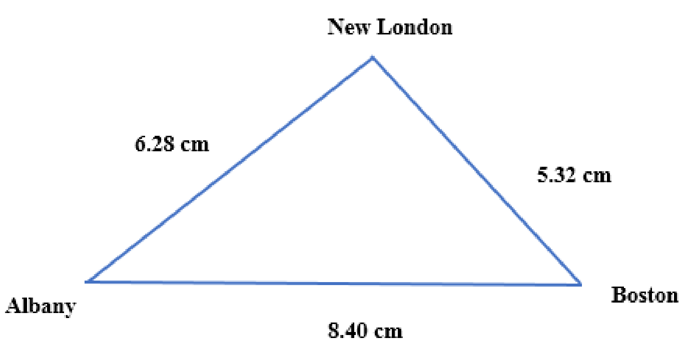
a. As depth increases both temperature and dissolved oxygen increase.
b. As depth increases dissolved oxygen increases and temperature decreases.
c. As depth increases both temperature and dissolved oxygen decrease.
d. As depth decreases both temperature and dissolved oxygen decrease.
e. As depth decreases dissolved oxygen decreases and temperature increases.

10. The attached gauge shows the power output of a small motor up to one-half horsepower (hp). Express the power output shown by the gauge in horsepower (hp), simplifying any fractions. Assume that the sections are evenly spaced.



a. 2/9 b. 3/4 c. 3/8 d. 3/16 e. 4/3

11. A triangle can be formed by drawing line segments on a map connecting New London, NH; Boston, MA; and Albany, NY. If the actual distance from New London to Boston is 88 miles, use the scaled triangle to calculate the distance between New London and Albany.

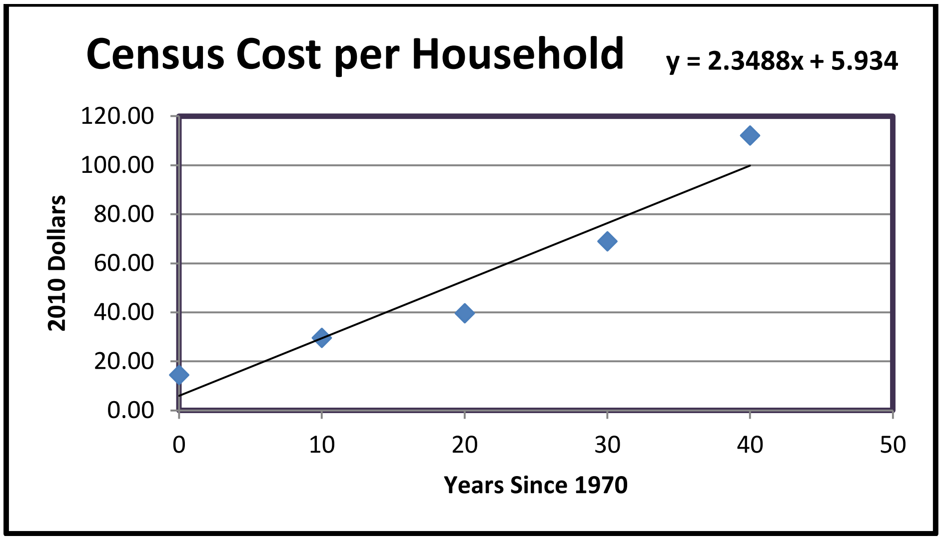


a. 55.7 b. 65.8 c. 103.9 d. 138.9 e. 176.0

12. Let $U_A = \frac{r}{1-U_B}$. Solve this equation for U_B in terms of U_A and r.

a. $\frac{r-U_A}{r}$ b. $\frac{r-U_A}{U_A}$ c. $\frac{1-r}{U_A}$ d. $\frac{U_A-r}{r}$ e. $\frac{U_A-r}{U_A}$

13. The following scatterplot shows the cost per household of the US census where $y = 2010\ dollars$ and $x = years\ since\ 1970$. What is the slope of the linear trendline, $= 2.3488x + 5.934$, telling us?



a. The cost per household in 1970 was \$2.35.
b. The cost per household has been increasing by \$2.35 per decade.
c. The cost per household was \$5.93 in 1970.
d. The cost per household has been increasing by \$5.93 per decade.
e. The cost per household has been increasing by \$2.35 per year.

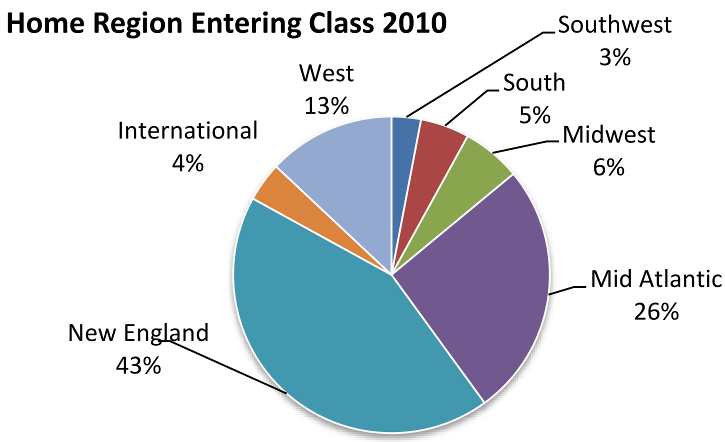
14. There were 480 students who entered as the Class of 2009. Of these, 430 submitted SAT scores by the time they enrolled. If you select a name at random from this class, what is the probability that the student did not submit an SAT score?

a. 5/43 b. 5/48 c. 43/48 d. 1.04% e. 0.104%

15. Rangers tagged and released 300 salmon into a Maine lake. A month later, fishermen on the lake were surveyed. They reported catching 80 salmon, 12 of which had tags. Using this sample, estimate the salmon population in the lake.

a. 450 b. 2000 c. 2400 d. 3000 e. 4500

The following graph displays the home region of the approximately 500 students who will enter Q College as the Class of 2014. Refer to it for problems #16-17.



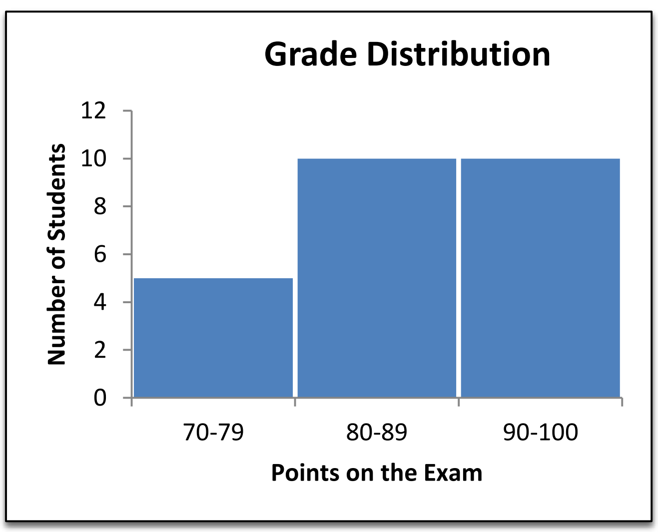
16. Choose the answer that best describes a comparison between the number of students from the Midwest and the number of International students.

a. The number of students from the Midwest is 2% more than the number of International students.
b. Twice as many students came from the Midwest as from International locations.
c. There are 25 more students from the Midwest than from International locations.
d. The number of International students is 25% more than the number from the Midwest.
e. The number of students from the Midwest is 50% more than the number of International students.

17. Of the entering students in 2010, 46% were male and 54% were female. Assume that gender is independent of the home region. What is the probability that a student selected at random is a female from the South?

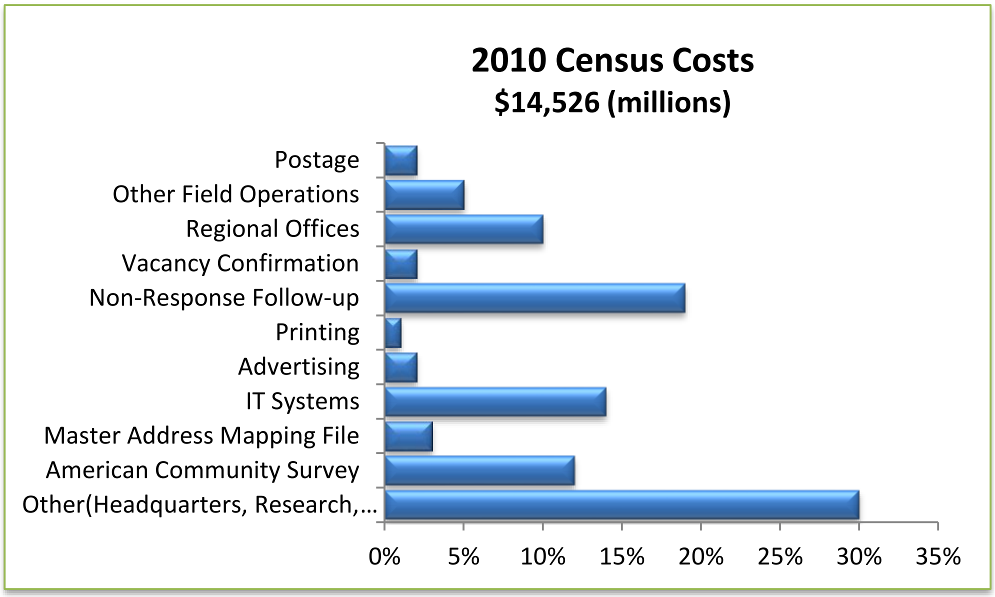
a. 0.027 b. 5/54 c. 0.09 d. 0.27% e. 0.9%

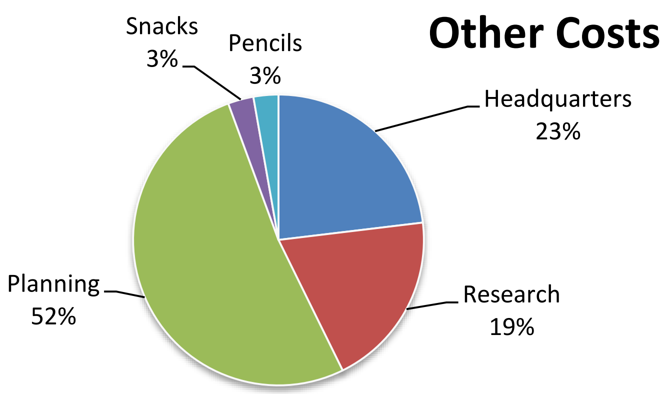
18. The grade distribution for the midterm in your Economics class with 25 students is given below. Which of the following statements below must be correct?



a. The highest possible class average (mean) for this exam is 93.
b. The class average (mean) for this exam is 87.
c. At least half of the people in the class got below an 85.
d. The lowest possible class average (mean) for this exam is 82.
e. At most, five students got a 100.

19. Using the charts below, compute how much was spent on ***Research*** for the 2010 Census.





a. $42 million   b. $828 million   c. $2,760 million   d. $4,358 million   e. $7,118 million

20. In 2009, the median earnings for men in the US workforce was $42,588 and the median earnings for women in the US workforce was $34,164. Which of the following is NOT a possible explanation for this discrepancy?

a. Women are paid less for the same work because of gender discrimination.
b. Men work more overtime.
c. There are more men in higher-paying jobs.
d. There are fewer women in the workforce.
e. Women take more time off of the work force for family leave.

THANK YOU!

THIS PROJECT SUPPORTED BY THE NATIONAL SCIENCE FOUNDATION, DUE 1140562

Demographic and Survey Questions

Please complete the following demographic information.

1. Please state your sex

   a. Female   b. Male

2. How many full years of college have you completed?

   a. 0   b. 1   c. 2   d. 3   e. 4 or more

3. Please state your race

   a. Hispanic or Latino   b. Asian   c. Black   d. White   e. American Indian

4. What is your major or intended area of study?

   a. Math/Science   b. Social Science   c. Humanities   d. Engineering or Technology   e. Other or Not Applicable

5. Have you passed a course in ……(circle all that apply)

   a. College Algebra?   b. Pre-Calculus   c. Calculus?   d. Statistics   e. None of These

Please complete the following survey choosing the letter that most closely captures your agreement/disagreement with the following statements:

6. Numerical information is very useful in everyday life.
   Strongly disagree **a** **b** **c** **d** **e** Strongly agree

7. Numbers are not necessary for most situations.
   Strongly disagree **a** **b** **c** **d** **e** Strongly agree

8. Quantitative information is vital for accurate decisions.
   Strongly disagree **a** **b** **c** **d** **e** Strongly agree

9. Understanding numbers is as important in daily life as reading and writing.
   Strongly disagree **a** **b** **c** **d** **e** Strongly agree

10. It is a waste of time to learn information containing a lot of numbers.
   Strongly disagree **a** **b** **c** **d** **e** Strongly agree

THE NATIONAL NUMERACY NETWORK

The Numbers Game: Understanding Numbers in the News, in Politics, and in Life

WSCUC QRAM Workshop   Cal Poly Pomona, CA   October 2-3, 2014

Eric Gaze
egaze@bowdoin.edu

1. How many Centenarians are there now in the US?
   a. 4,000
   b. 15,000
   c. 35,000
   d. 53,000
   e. 106,000
2. How many homeless people are there in the US?
   a. 10,000
   b. 50,000
   c. 100,000
   d. 500,000
   e. 3,000,000
3. What percentage of students loans have defaulted since 2005?
   a. 2%
   b. 8%
   c. 20%
   d. 35%
   e. 60%
4. How many anorexia deaths are there in the US each year?
   a. 70
   b. 500
   c. 2,000
   d. 150,000
   e. 300,000
5. What is the US Household debt per capita?
   a. $500 per person
   b. $2,000 per person
   c. $45,000 per person
   d. $120,000 per person
   e. $1,000,000 per person

6. Use the number 41.1 from the table below in a sentence.

Black and White Victimizations and Arrests for Crimes of Violence 1997			
	Number	Percent	Rate[i]
Victimization[ii]			
White	7,068,590	82.1	37.1
Black	1,306,810	15.2	46.8
Arrests[iii]			
White	284,523	56.8	1.5
Black	205,823	**41.1**	7.4

7. If a 1% risk of contracting a disease increases by 5%, then the new risk is:
   a. 1.05%
   b. 1.5%
   c. 2%
   d. 6%
   e. 15%
8. The average US Household income is:
   a. $41,000
   b. $52,000
   c. $67,000
   d. $83,000
   e. $100,000 (oops! Didn't realize how low these were…)

a. $200,000
b. $250,000
c. $500,000
d. $1,000,000

9. The household income needed to be in the top 10%:
   a. $140,000
   b. $180,000
   c. $230,000
   d. $250,000
   e. $330,000
10. The household income/net worth needed to be in the top 1%:
    a. $140,000/$1,000,000
    b. $250,000/$3,000,000
    c. $300,000/$8,000,000
    d. $550,000/$10,000,000
    e. $1,250,000/$25,000,000
11. The top 1% of household income earners pay what share of income tax:
    a. 5%
    b. 8%
    c. 14%
    d. 22%
    e. 35%

[i] Per 1,000 people aged 10 and above
[ii] Estimates for personal victimization (crimes of violence) derived from 1997 National Crime Victimization Survey
[iii] Arrests for violent crime reported in 1997 Uniform Crime Reports

THE NATIONAL NUMERACY NETWORK

Quantitative Reasoning (QR):
A Program for Student Success

Eric Gaze , Bowdoin College

WSCUC QRAM Workshop

October 2, 2014

Outline:
- QR Course
- QR Program
- QLR Assessment

THE NATIONAL NUMERACY NETWORK

"A well-established and highly studied construct, **numeracy** encompasses not just mathematical ability but also a disposition to engage quantitative information in a reflective and systematic way and use it to support valid inferences ."

-Dan Kahan et.al.

"Quantitatively literate citizens need to know more than formulas and equations. They need a predisposition to look at the world through mathematical eyes, to see the benefits (and risks) of thinking quantitatively about commonplace issues, and to approach complex problems with confidence in the value of careful reasoning. Quantitative literacy **empowers** people by giving them tools to think for themselves, to ask intelligent questions of experts, and to **confront authority confidently**. These are skills required to thrive in the modern world."

-*Mathematics and Democracy* 2001

In short, how do we create a ~~mathematics~~ QR curriculum which teaches our students how to **THINK**?

Is Algebra Necessary?

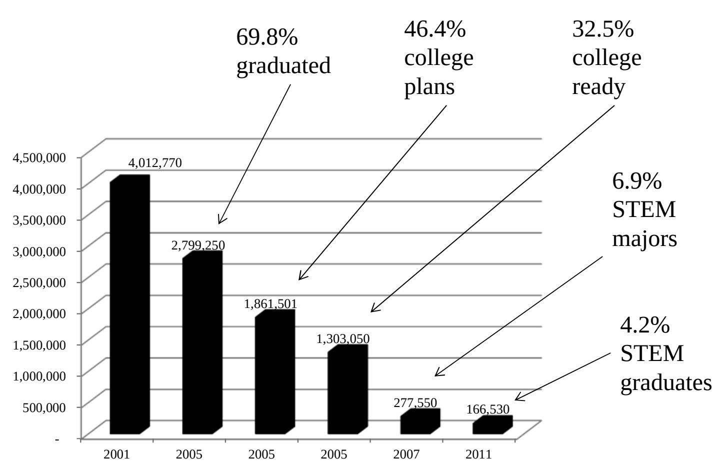
- Andrew Hacker Professor Emeritus CUNY
New York Times July 29, 2012

"A typical American school day finds some six million high school students and two million college freshman struggling with algebra."

"I'm not talking about **quantitative skills**, critical for informed citizenship and personal finance, but a very different ballgame."

"What is needed is **not textbook formulas** but greater understanding of where various numbers come from and what they actually convey."

2001 Cohort 9th Graders



This is not a pipeline… it is a trickle. 60% of STEM workforce is 45 and older.

How Much Math Do We Really Need?

- Professor Emeritus U. Ill. Chicago
Washington Post 10/22/2010

"Unlike literature, history, politics and music, math has **little relevance** to everyday life."

"All the math one needs in real life can be **learned in early years** without much fuss."

"Most adults have no contact with math at work, nor do they curl up with an **algebra** book for relaxation."

THE NATIONAL NUMERACY NETWORK

Algebra as Business Math

Circa 1200 CE

"Few in business today make use of the mathematics they learned in school. **Spreadsheets** have entirely different requirements."

"Mathematical reasoning in workplaces **differs markedly** from the algorithms taught in school."

"Make no mistake; the revolution in business math created by the spreadsheet is conceptual as well as physical. **It changes the way people in business think** about and approach problems as well as the way they work through results. It enables them to quantify a whole new range of problems."

Impatience with Irresolution
Sitcom Culture: Problems should not take more than 30 minutes, be easy to understand, and have a happy ending.

Problem Solving vs. Modeling

-***Modeling for Insight***
Powell and Batt

- Well Structured Problems
  - Objective Clear
  - Assumptions Obvious
  - Data available
  - One right answer
- Examples:
  - Solve 2x -5/x =12 for x.
  - Balance the books.
  - Do your taxes.
    - Hopefully this is well structured!
- Ill Structured Problems
  - Objectives, Assumptions, Data ambiguous
- Examples
  - Should the Red Cross pay for blood donations?
  - Should we tax soda?
  - How much should an advertiser allocate to creative over delivery of ad?
  - Should spreadsheets be taught K-12?

Tolerance for Ambiguity

Problem Solving vs. Modeling

-***Modeling for Insight***
Powell and Batt

- Ill Structured Problems are **Explored**
  - Make assumptions
  - Formulate Hypotheses
  - Generate Insights (don’t “solve!”)
- Modeling Process
  - Frame the Problem
  - Diagram the Problem
    - Influence Diagrams (relationships between variables)
  - Build a Model
    - **Spreadsheet Engineering**/ Parametrization
    - Sensitivity/ Strategy Analysis
  - Generate Insights
    - Iterate!

N Ways to Apply Algebra with the New York Times

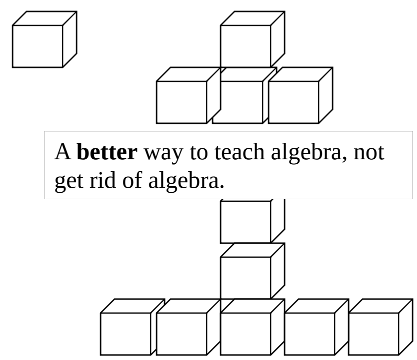
-***Patrick Honner***

September 26, 2012

- Amortizatio
  - Buy versu
  - Make Ass "solve!")
- Evaluating (
  - "Use data rank scho
- Calculating
  - "Create sc
- Metro Card Math
  - Unlimited card or ride by ride?
- Olympic Algebra
  - "Compare and contrast average speeds of athletes over time, across events, and by gender."
- Stock Portfolios
  - Compound interest formula, exponential growth, and compare different rates of return.

Modeling Process
- Frame the Problem
- Diagram the Problem
  - Influence Diagrams (relationships between variables)
- Build a Model
  - **Spreadsheet Engineering**/ Parametrization
  - Sensitivity/ Strategy Analysis
- Generate Insights
  - Iterate!

Building Blocks



How many blocks will there be in the n^{th} building?

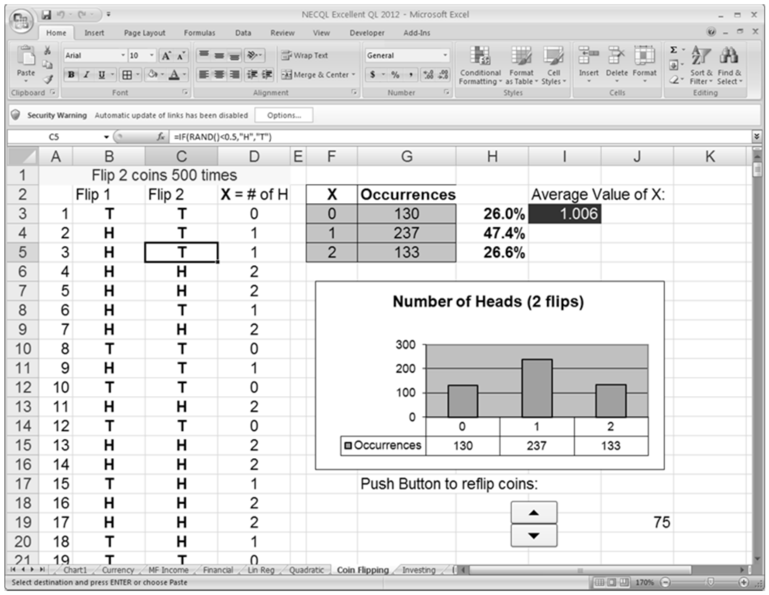
A **better** way to teach algebra, not get rid of algebra.

Building N	Number of Blocks		
n	Recursion	1 + 3(n-1)	3n - 2
1	1	1	1
2	4	4	4
3	7	7	7
4	10	10	10
5	13	13	13

Building Number	Number of Blocks		
n	Recursion	1 + 3(n-1)	3n - 2
1	1	=1+3*(A3-1)	=3*A3-2
2	=B3+3	=1+3*(A4-1)	=3*A4-2
3	=B4+3	=1+3*(A5-1)	=3*A5-2
4	=B5+3	=1+3*(A6-1)	=3*A6-2
5	=B6+3	=1+3*(A7-1)	=3*A7-2

Probability and Coin Flips

Math as a LAB science.
Empirical Observations



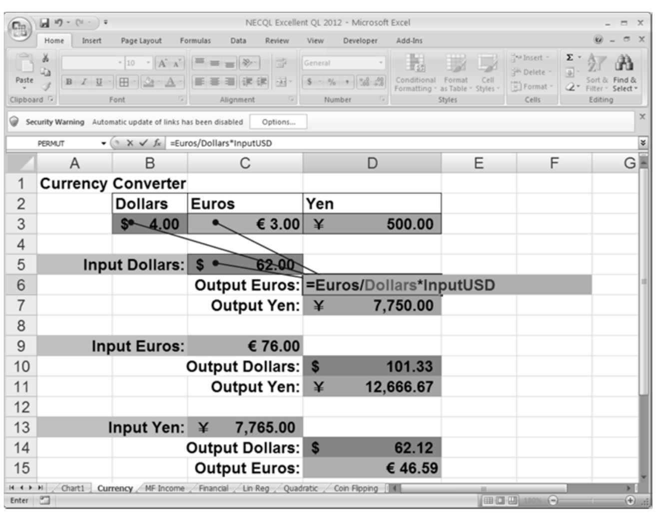
	Flip 1	Flip 2	X = # of H
1	T	T	0
2	H	T	1
3	H	T	1
4	H	H	2
5	H	H	2
6	H	T	1
7	H	H	2
8	T	T	0
9	H	T	1
10	T	T	0
11	H	H	2
12	T	T	0
13	H	H	2
14	H	H	2
15	T	H	1
16	H	H	2
17	H	H	2
18	T	H	1
19	T	T	0

X	Occurrences	
0	130	26.0%
1	237	47.4%
2	133	26.6%

Ratio and Proportion

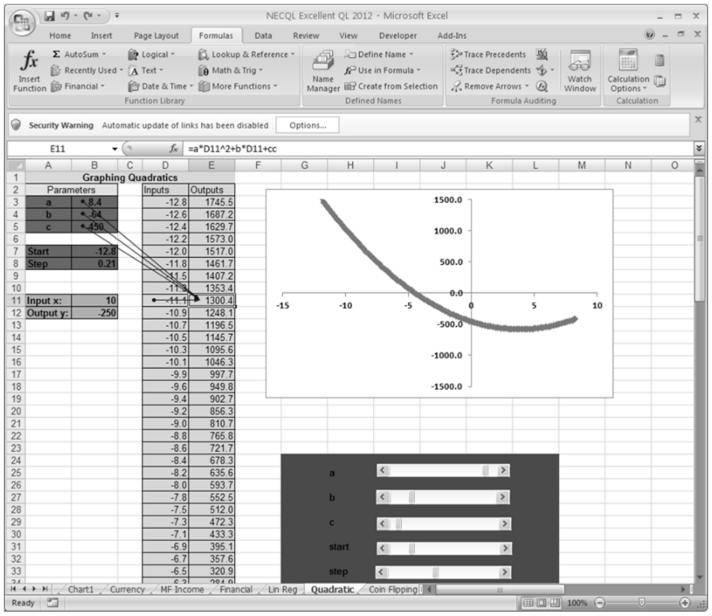
E = 4/3*D

Or is it
E=3/4*D ??



	Dollars	Euros	Yen
Currency Converter			
	$ 4.00	€ 3.00	¥ 500.00
Input Dollars:	$ 62.00		
		Output Euros:	=Euros/Dollars*InputUSD
		Output Yen:	¥ 7,750.00
Input Euros:	€ 76.00		
		Output Dollars:	$ 101.33
		Output Yen:	¥ 12,666.67
Input Yen:	¥ 7,765.00		
		Output Dollars:	$ 62.12
		Output Euros:	€ 46.59

Graphing in Real Time



Modeling Car Cost

	Focus	Prius		
Cost	$20,000.00	$33,000.00		
			Gallons per 100 miles	
MPG Hway	28	45	3.571	2.222
MPG City	22	37	4.545	2.703
			Gallons Used	
Miles Hway	8,000		285.71	177.78
Miles City	12,000		545.45	324.32
Price per Gallon	$ 3.86	Total Gallons	**831.17**	**502.10**
		Cost:	**$ 3,208.31**	**$1,938.11**
		Gas Savings per year:	$ 1,270.20	
		Extra Cost:	$13,000.00	
		Years to recoup:	**10.23**	years

Modeling Car Cost

THE NATIONAL NUMERACY NETWORK

	Focus	Prius		
Cost	$ 20,000.00	$ 33,000.00		
			Gallons per 100 miles	
MPG Hway	28	45	3.571	2.222
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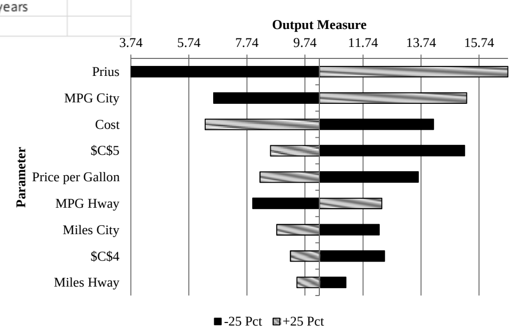
			Gallons Used	
Miles Hway	8,000		285.71	177.78
Miles City	12,000		545.45	324.32
Price per Gallon	$ 3.86	Total Gallons	831.17	502.10
		Cost:	$ 3,208.31	$ 1,938.11
		Gas Savings per year:	$ 1,270.20	
		Extra Cost:	$ 13,000.00	
		Years to recoup:	10.23	years

Which parameter has the greatest impact on the years to recoup extra cost of the Prius?

Tornado Sensitivity Chart



Is Algebra Necessary?
Yes! And we can use spreadsheets and modeling to help teach students why.

Counting 1, 2, 3,…

- They Counted Wh…
  - Centenarians?
    - 1970: 106,441
    - 1980: 32,194
    - 2010: 53,364
  - Homeless?
    - 1980: 3,000,000
    - Who is "homeless"?
- Student Loan Default Rates Rise Sharply in Past Year
  - 8.8% of all borrowers defaulted in the past year ending Sept. 30, up from 7%...
    - What does "default" mean?
    - 2 year default rate
  - Only 37% have paid back on time since 2005

Damned Lies and Statistics: *The Social Construction of Statistics* by Joel Best

1. Who created this statistic?
2. Why was this statistic created?
3. How was this statistic created?

Counting 1, 2, 3,…

- How big is that?
  - Keen sense of proportion… RATIOS!
  - Anorexia Deaths: 150,000 (1994)
    - Mutant Statistic: only 55,500 women 15-44 died that year!
- US Household Debt
  - Record $13.8 trillion in 2011
- Is that a BIG number?
  - ~$46,000 per person
  - $884/week per person for 1 year (using $15.6 billion as a yardstick)

Percentage of What?

- Drunk drivers account for 1/3 of all accidents…
  - So sober drivers are twice as dangerous?

Fraction of Accidents due to:	
Drunk Drivers	1/3
Sober Drivers	2/3

  - 25-34 year olds get in 10 times as many accidents as 16 year olds…

	# accidents 2009:	**# drivers:**
16 year olds	229	1,000
25-34 year olds	89	1,000

- Men account for 55% of all accidents
  - But drive 63% of the miles

"41.1% of blacks were arrested in 1997, which means 7.4 out of every 1,000 people was a violent black criminal…"

Really? So 56.8% of whites were arrested for violent crimes as well?...

Black and White Victimization's and Arrests for Crimes of Violence 1997			
	Number	Percent	Rate
Victimization			
White	7,068,590	82.1	37.1
Black	1,306,810	15.2	46.8
Arrests			
White	284,523	56.8	1.5
Black	205,823	**41.1**	**7.4**

Quantitative Literacy: Communicating (Reading and Writing) with Numbers NOT just Arithmetic

What's the Chance of That?

- One slice of bacon a day increases risk of colorectal cancer in men by 21%
  - For ev … sk of breast cancer increases by 6%...

    $1.00 increases to $1.05 is clearly a 5% increase.
  - **Oops!** Risk of breast cancer increases by 6% for every extra alcohol

    1% increases to 6% is clearly NOT 5% increase.
  - Where did we start?
- Start: 5 in 100 men get colorectal cancer in their lifetime.
  - Add bacon every day and about 6 out of 100 would.
- Start: 9 in 100 women will get breast cancer in their lifetime.
  - Add 2 drinks a day and about 10 in a 100 would.

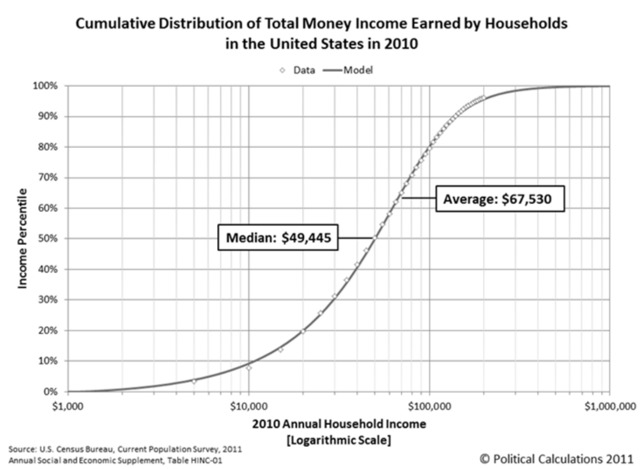
“In other words, translating a ratio to a percentage is not just a mathematical operation, but also a rhetorical practice in which artistic appeals are manipulated.” - Joanna Wolfe

- Women are 68% percent more likely than men to experience depression in their lifetimes.
- Over 75% of women never experience depression in their lifetime.
- 17.1 percent of individuals have experienced depression in their lifetime.
- Over 1 in 5 women and 1 in 8 men have experienced depression in their lifetimes.
- Approximately four of every ten depressed individuals is a man.

Statistics: 21.3% of women and 12.7% of men have experienced depression in their lifetime.

How Average…

- Statistical Literacy:



How Average…

- Speaking of Mean People:
- What household income do you need to make to be in the top 10%?
- What percentage of income tax do the top 1% pay?
- How many standard deviations from the mean is someone in the top 0.01% at $35 million? (N = 11,000)
  - 92 standard deviations
  - A person who is 92 sd from mean in height would be 27 feet tall!

Math 050: Quantitative Reasoning

- Pre-Post Assessments

Math 1050: QR Spring 2011			
	Pre-Qzscore	Post-Qzscore	Total Improvement
Mean	-1.219	-0.253	**0.966 sd**
StDev	0.905	0.913	
Math 50: QR Fall 2011			
	Pre-Qzscore	Post-Qzscore	Total Improvement
Mean	-1.337	-0.210	**1.127 sd**
StDev	0.670	0.913	
Math 50: QR Fall 2012			
	Pre-Qzscore	Post-Qzscore	Total Improvement
Mean	-1.45	-0.230	**1.220 sd**
StDev	0.694	0.607	

The QLR Assessment Project

- NSF TUES: Transforming Undergraduate Education in STEM, DUE 1140562
- Type I, 2 year pilot project
  - Create QLRA instrument
  - Create Website for Administering Test
  - Establish national baseline of QLR scores
- Combined Bowdoin, Colby-Sawyer, and Wellesley exams
- 2012 Mean 13.44 out of 23 (58.4%; sd = 5.35)
- 2013 Mean 9.22 out of 20 (46.1%; sd = 5.02)
- Co-PI's:
  - Semra Kilic-Bahi Colby Sawyer College
  - Linda Misener Southern Maine Community College

Note: the 2013 test was reduced to 20 questions.

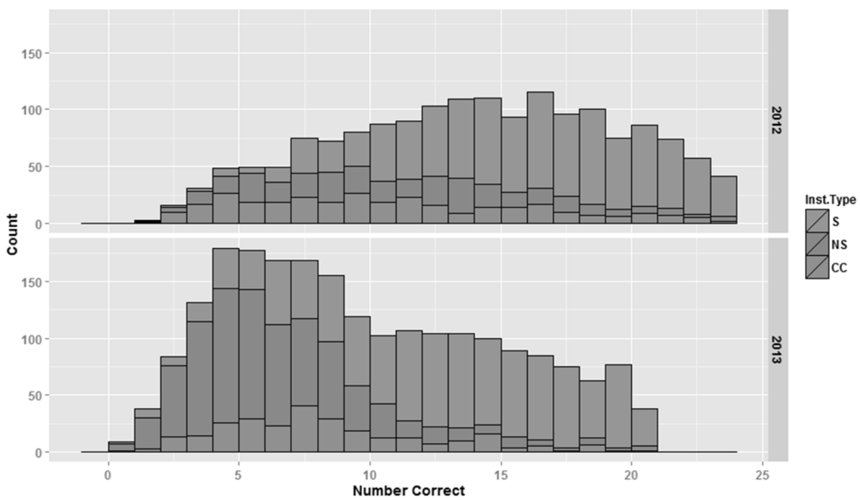
The QLR Assessment Project

Institution Type	2012 Mean %	2012 Std. Dev.	2013 Mean %	2013 Std. Dev.
2-Year	**44.7**	23.4	**39.3**	20.2
Selective 4-year	**66.4**	20.0	**59.7**	22.8
Non-selective 4-year	**47.2**	21.6	**30.1**	17.9
Total	**58.4**	**23.3**	**45.6**	**24.7**

Note: the significant drop in mean score due to increase in non-selective school participation.

Institution Type	2012 N	2012 %	2013 N	2013 %
2-Year	314	**18.9**	273	**12.6**
Non-selective 4-year	334	**20.1**	811	**37.3**
Selective 4-year	1011	**60.9**	1088	**50.1**
Total	1659	100.0	2172	100.0

The QLR Assessment Project



Again you can see influence of non-selective school participation rates.

WHAT CAN "Q" DO FOR YOU?

The Bowdoin QR Exam

BOWDOIN COLLEGE

- 30 question entrance exam used for advising
  - Under 50% on Bowdoin Q-exam criteria for Math 050 (N = 50)
- Lessons Learned
  - Replace procedural, algorithmic questions with more involved reasoning, critical thinking questions.
  - Ask students to interpret tables and charts rather than doing it for them.
  - Focus on quantitative literacy, using numbers in meaningful sentences rather than just computation.
  - Ask students to postulate possible explanations for statistics rather than traditional logic games.

WHAT CAN "Q" DO FOR YOU?

BOWDOIN COLLEGE

The Bowdoin QR Exam

- 30 question entrance exam used for advising
  - Under 50% on Bowdoin Q-exam criteria for Math 050 (N = 50)
- Significant predictor of GPA (N = 3,000)
  - Cumulative GPA   r = 0.39
  - MCSR GPA   r = 0.48
- Strongly correlated with 1st year Cum GPA   r = 0.48
- Multivariate Regression Models (R^2 = 0.30 Cum GPA and R^2 = 0.36 MCSR GPA)

WHAT CAN "Q" DO FOR YOU?

BOWDOIN COLLEGE

Holding All Other Variables Constant

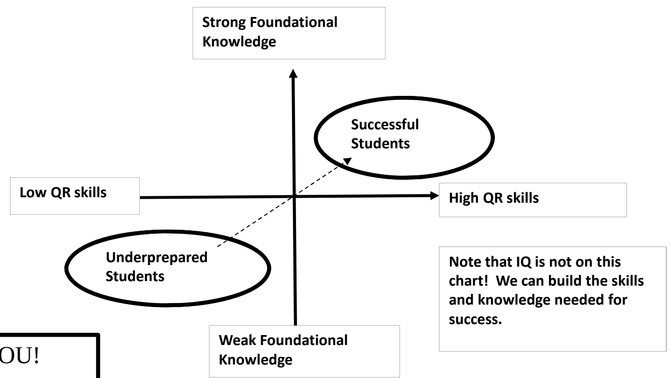
	Q-score 30%	Q-score 80%
Cum GPA	3.2	3.5
MCSR GPA	2.7	3.5

- M … Cum GPA and R…
- T … ference in GPA associated with a 10 percentage point increase in respective aptitude test, with **all** other variables in model held constant.

Cumulative GPA Multivariate Regression Coefficients		
Math SAT	Q-score	Verbal SAT
0.0345	0.0603	0.0857
MCSR GPA Multivariate Regression Coefficients		
Math SAT	Q-score	Verbal SAT
0.1711	0.1599	0.0357

Scaffolding Student Success

- Math 1050: QR is an ENTRY point
- Math 1050: QR as a foundation for Calculus and Social Science
- Math 1050: QR is an EXIT point
- Future Work



THANK YOU!
Questions?

WASC Senior College and University Commission | EDUCATIONAL PROGRAMS

Breakout 3

Why ePortfolios? Why Now? Documenting Learning with ePortfolios

H.Chen

Why ePortfolios? Why now?
Documenting Learning with ePortfolios

Helen L. Chen – Stanford University
WASC Quantitative Reasoning &Assessment in Majors
October 2, 2014

In our general education programs, do students have the opportunity to demonstrate **what they know** and **can do**? Can they:

1. self-assess their own abilities; and
2. paint a picture of accomplishment for employers?

-- Debra Humphreys, 6/1/13

In our <u>**majors**</u>, do students have the opportunity to demonstrate **what they know** and **can do**? Can they:

1. self-assess their own abilities; and
2. paint a picture of accomplishment for employers?

---

ePortfolios and Folio Thinking

Portfolio: A purposeful selection of artifacts together with reflections that represent some aspect of the owner's learning

A culture of **Folio Thinking** provides structured opportunities for students to:

1. create learning portfolios
2. reflect on learning experiences

emphasizing integration, synthesis, and self-understanding

---

ePortfolio Purposes
(Lorenzo & Ittelson, 2005)

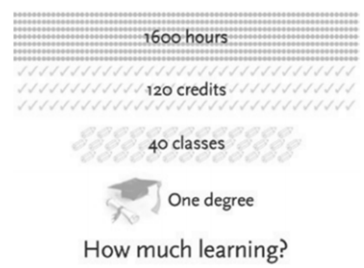
1. **Showcase**
   - Finding a job
   - Highlighting achievements, skills, and abilities
2. **Assessment**
   - Tracking development within a course or program
   - Performance monitoring and evaluation
3. **Learning**
   - Educational Planning, advising, mentoring
   - Documenting knowledge, skills, and abilities over time
4. **Hybrid** (some combination of the above)

Showcase Portfolios vs. Learning ePortfolios

Showcase ePortfolio	**Learning ePortfolio**
<u>Purposes</u>: Showcase	<u>Purposes</u>: Exploratory & Developmental over time
<u>Content</u>: Curated collection highlighting exemplary work; formal and/or verified	<u>Content</u>: Could include works in progress, drafts, goals, plans
<u>Focus</u>: the ePortfolio *product*	<u>Focus:</u> the ePortfolio *process*
<u>Goals</u>: Outward facing, networking; your professional identity	<u>Goals</u>: Self-knowledge and understanding; growth over time; your intellectual identity
<u>Audience</u>: Employers, grad schools, professionals, the public	<u>Audience:</u> *Selected* mentors, advisors, faculty, alumni, peers & family

Why ePortfolios?
Why now?

Credit Hour → Degree → Learning?



Amy Latinen, *Cracking the Credit Hour*, September 2012, New American Foundation and Education Sector


THE CHRONICLE of Higher Education

Commentary

Comments (55)

April 29, 2013

College Graduates Deserve Much More Than Transcripts

By Kevin Carey

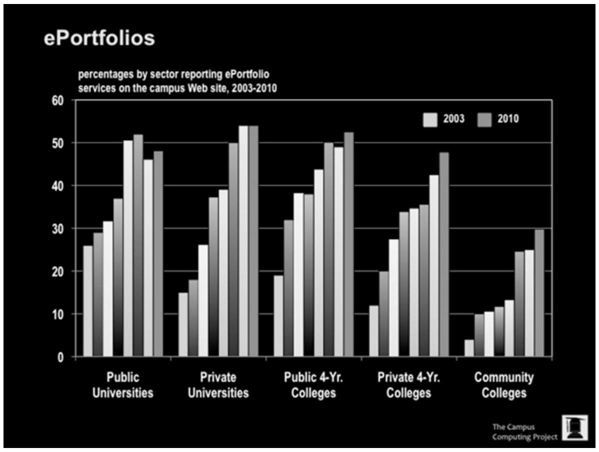
College transcripts are horrible. I say this not as a columnist but as an employer. Whenever my nonprofit policy group advertises a position, we get hundreds of résumés. Every applicant is a college graduate. But when it comes to winnowing the field to 10 or 15 semifinalists, we have almost no useful information about what they learned in school.

Their résumés tell us if they attended a selective institution, which provides some insight into what they were like at age 17. But we're not in

*College transcripts are horrible… when it comes to winnowing the field to 10 or 15 semifinalists, we **have almost no useful information about what they learned in school.***

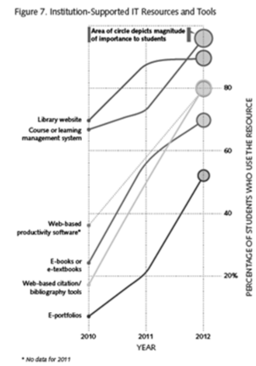
*But what does a college degree really tell employers about how much an applicant knows, about **how much they learned** to earn that credential?*

Why ePortfolios?



2012 ECAR National Study of Undergraduate Students and Information Technology

7x as many students used ePortfolios in 2012 (52%) vs. 2010 (7%)

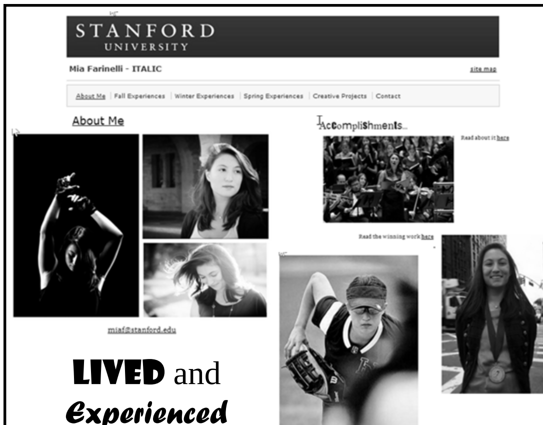


2013: 53% of students reported using ePortfolios

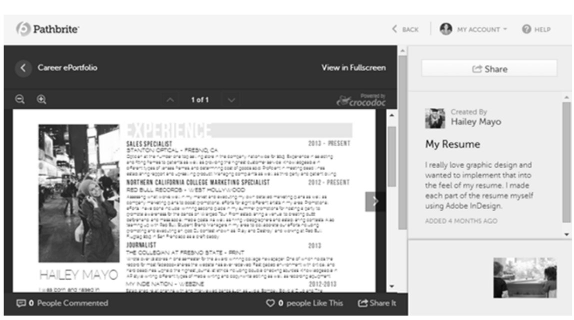
Higher education as it is…

Delivered

LIVED



LIVED and *Experienced*



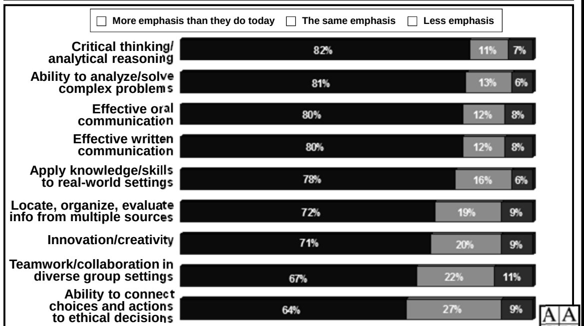
HART RESEARCH ASSOCIATES

It Takes More Than A Major:

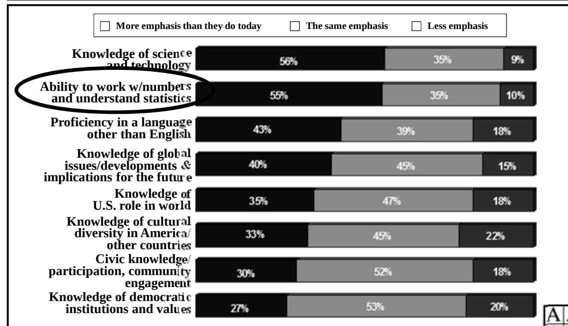
Employer Priorities for College Learning and Student Success

Key findings from survey among 318 employers
Conducted January 9 – 13, 2013
for
Association of American Colleges and Universities

Majorities of employers want colleges to place more emphasis on selected outcomes.



Majorities of employers want colleges to place the same or more emphasis on other outcomes.

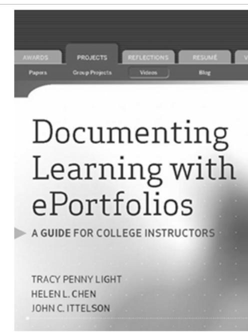


…we need to apply new technologies to the primary tool of traditional certification, the diploma. We need to take what now exists as a dumb, static document and turn it into a ***richer, updateable, more connected record of a person's skills, expertise, and experience.***

ePortfolio Implementation Framework

(Chen & Penny-Light, 2010; Penny-Light, Chen, & Ittelson, 2012)

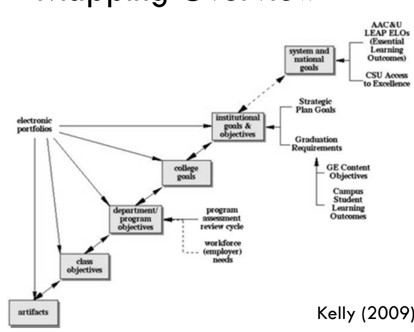
1. Defining Learning Outcomes
2. Designing Learning Activities
3. Identifying and Understanding Learners and Stakeholders
4. Informing Assessment of Student Learning
5. Using ePortfolio Tools and Technologies
6. Evaluating the Impact of Your ePortfolio Initiative



Defining Learning Outcomes

- What learning outcomes are you currently implementing or considering for your ePortfolio initiative?
- What types of learning do you want to capture and document?

Mapping Overview



Kelly (2009)

http://teachingcommons.cdl.edu/eportfolio/resources/dop/mapping.html

Mechanical Engineering

Catalog Home » School of Engineering » Mechanical Engineering

Overview | Bachelor's | Minor | Master's | Doctoral | Faculty | Overseas | Related Courses

Learning Outcomes (Undergraduate)

The department expects undergraduate majors in the program to be able to demonstrate the following learning outcomes. These learning outcomes are used in evaluating students and the department's undergraduate program. Students are expected to demonstrate:

1. an ability to apply knowledge of mathematics, science, and engineering.
2. an ability to design and conduct experiments, as well as to analyze and interpret data.
3. an ability to design a system, component, or process to meet desired needs.
4. an ability to function on multidisciplinary teams.
5. an ability to identify, formulate, and solve engineering problems.
6. an understanding of professional and ethical responsibility.
7. an ability to communicate effectively.
8. the broad education necessary to understand the impact of engineering solutions in a global and societal context.
9. a recognition of the need for and an ability to engage in life-long learning.
10. a knowledge of contemporary issues.
11. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice..
12. the ability to apply advanced mathematics through multivariate calculus and differential equations.
13. the ability to work professionally in both thermal and mechanical systems areas including the design and realization of such systems.

25

An ability to function on multidisciplinary teams

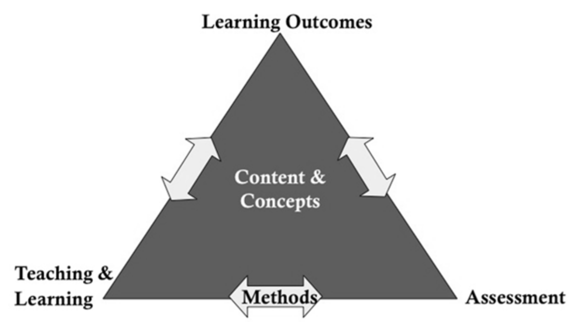
FIRST Robotics

Stanford Wushu

Designing Learning Activities

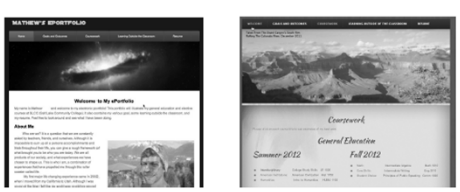
- Given your outcomes, what **activities** can you design to best guide the ways that learners use the ePortfolio to document their learning?
- How will their learning be captured and documented in the ePortfolio?

Alignment in Course/Program Design



ePortfolio Assessment of General Education

Quantitative and Information Literacy--2013



Pages from the ePortfolios of Matthew Potts and Adam "Eli" Spikell. Used with Permission.

Salt Lake Community College

David Hubert, ePortfolio Director
Kati Lewis, ePortfolio Coordinator

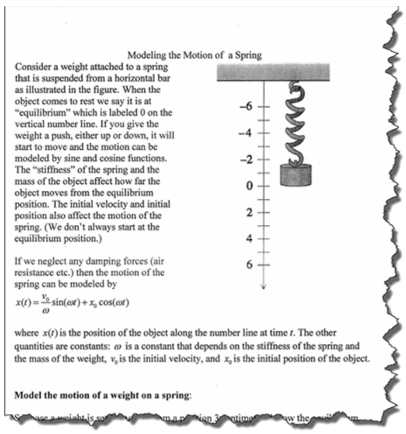
Salt Lake Community College

MATH 1050 **COLLEGE ALGEBRA** **FALL 2013**

INSTRUCTOR:
OFFICE:
PHONE / EMAIL:
CONSULTATION:
INSTRUCTOR WEB SITE:
MATH DEPT WEB SITES: http://active.slcc.edu/math/, https://sites.google.com/site/slccmathdepartment/

General Education Statement: This course fulfills the **Quantitative Literacy (QL)** requirement for the General Education Program at Salt Lake Community College. It is designed not only to teach the inform and skills required by the discipline, but also to develop vital workplace skills and to teach strategies and skills that can be used for life-long learning. General Education courses teach basic skills as well as br

General Education ePortfolio—Each student in General Education courses at SLCC maintains a General Education ePortfolio. Instructors in every Gen Ed course will ask you to put at least one assignment from th course into your ePortfolio, and accompany it with reflective writing. **It is a requirement in this class for to add to your ePortfolio**, and this syllabus details the assignments and reflections you are to include. You ePortfolio will allow you to include your educational goals, describe your extracurricular activities, and post your resume. When you finish your time at SLCC, your ePortfolio will then be a multi-media showcase of



Modeling the Motion of a Spring

Consider a weight attached to a spring that is suspended from a horizontal bar as illustrated in the figure. When the object comes to rest we say it is at "equilibrium" which is labeled 0 on the vertical number line. If you give the weight a push, either up or down, it will start to move and the motion can be modeled by sine and cosine functions. The "stiffness" of the spring and the mass of the object affect how far the object moves from the equilibrium position. The initial velocity and initial position also affect the motion of the spring. (We don't always start at the equilibrium position.)

If we neglect any damping forces (air resistance etc.) then the motion of the spring can be modeled by

$$x(t) = \frac{v_0}{\omega}\sin(\omega t) + x_0\cos(\omega t)$$

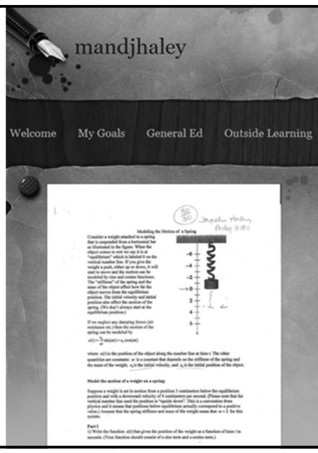
where $x(t)$ is the position of the object along the number line at time t. The other quantities are constants: ω is a constant that depends on the stiffness of the spring and the mass of the weight, v_0 is the initial velocity, and x_0 is the initial position of the object.

Model the motion of a weight on a spring:

__ePortfolio Posting__:

All Math 1060 students must post a copy of the mass-spring project in their General Education eportfolio. The completed project should be scanned to a pdf file and posted in that form. The eportfolio must be linked to MyPage. Students must also include some reflective writing about the project in the ePortfolio. The reflective writing should include a response to the following :

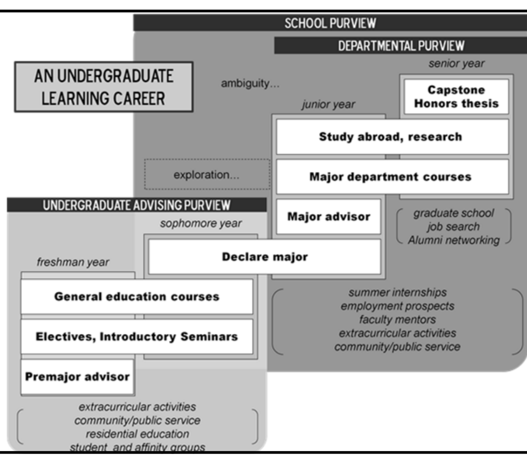
Give some examples of mass-spring systems important in everyday life. Describe why it would be important to understand the amplitude, period and frequency of these systems. Did this project change the way you think about how trigonometry can be applied to the real world? State what ideas changed and why. If this project did not change the way you think, write how this project gave further evidence to support your existing opinion about applying trigonometry. Be specific.

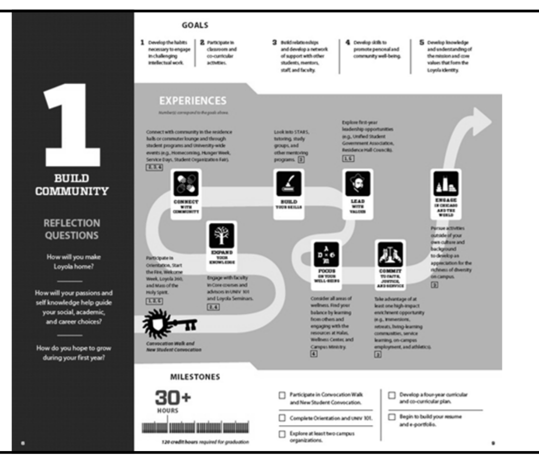


The intent of this assignment was to help us to understand some of the ways trigonometry can be used in everyday life. …At first I was really confused by this process, but in the end it all came together and made sense.

Identifying & Understanding Learners and Stakeholders

- Who are we designing the learning experience for?
- What are their characteristics?
- What technologies are they comfortable with?
- What support will they need to create their ePortfolios?

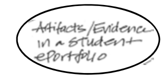




What does the learning career for your institution, program, or course look like?

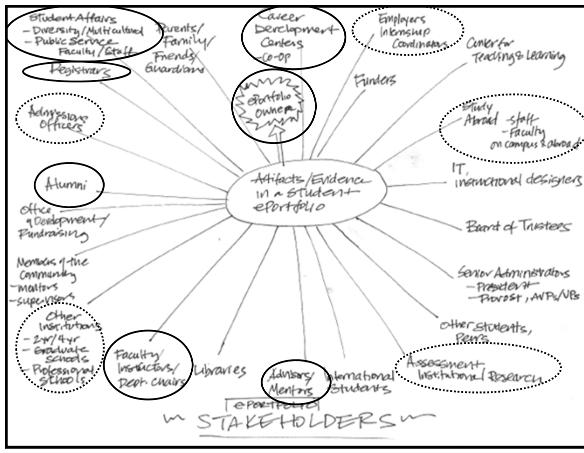
- What are the **major milestones** in the student's academic trajectory?
- When and where is **reflection** occurring, e.g. assignments, RA applications, jobs, internships, fellowships, scholarships?
- **Who** are students interacting with along the way? **What faculty, staff, offices, programs, services** are supporting students in their educational trajectory?

Sketch... who are the stakeholders for your ePortfolio project.



Share your map…

- Who are the most important stakeholders for the ePortfolio?
- What stakeholders are missing?
- How do you envision the ePortfolio meeting the stakeholder needs?



Stakeholder: Students

WHAT ARE YOU TAKING AWAY FROM YOUR STANFORD EDUCATION?

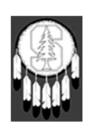
SKILLS
- Communication
- Teamwork
- Problem solving

PERSONAL VALUES & ATTRIBUTES
- Discipline
- Adaptability
- Responsibility
- Integrity

WELLNESS

EXPERIENCES
- Courses
- Clubs & organizations
- Events (Powwow, Luau)
- Outreach
- Projects

EVIDENCE
- Writing samples
- Multimedia
- Promotional materials
- Multimedia – photos, videos



What Employers Want

(NACE, 2014)

Figure 1: Employers rate the importance of candidate skills/qualities

Skill/Quality	Weighted average rating*
Ability to work in a team structure	4.55
Ability to make decisions and solve problems	4.50
Ability to plan, organize, and prioritize work	4.48
Ability to verbally communicate with persons inside and outside the organization	4.48
Ability to obtain and process information	4.37
Ability to analyze quantitative data	4.25
Technical knowledge related to the job	4.01
Proficiency with computer software programs	3.94
Ability to create and/or edit written reports	3.62
Ability to sell or influence others	3.54

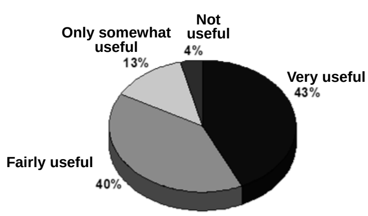
*5-point scale, where 1=Not at all important; 2=Not very important; 3=Somewhat important; 4=Very important; and 5=Extremely important

Source: *Job Outlook 2014*, National Association of Colleges and Employers

Stakeholder: Employers

Employers say that an electronic portfolio of students' work and knowledge areas would be useful in evaluating candidates for hire.

In addition to a recent college graduate's résumé and college transcript . . . how useful would it be to see an electronic portfolio of student work that demonstrates accomplishment in key skill and knowledge areas (effective communication, knowledge in their field, evidence-based reasoning, ethical decision-making)?

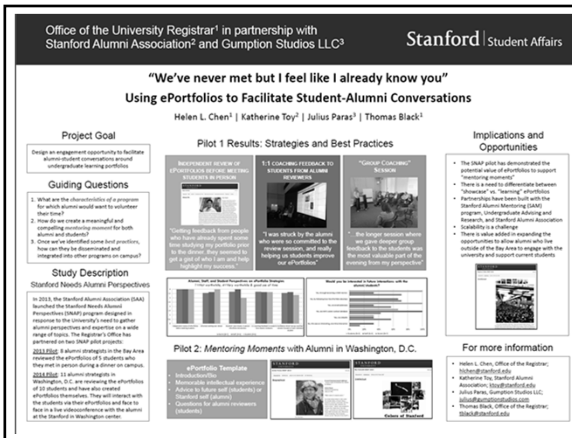


45 **It Takes More Than A Major – January 2013 – Hart Research *for*** AAC&U

ePortfolios and Employers
Proposed Research Questions

1. **Will employers look at ePortfolios?** If yes, under what circumstances or conditions?
2. Are students who create ePortfolios **better prepared for job interviews**? Do they write **more effective cover letters**? Are they more competitive candidates?
3. What is the value of Folio Thinking and ePortfolios in the **recruitment, interviewing, & hiring processes**?
4. What are some strategies or best practices for **socializing and educating employers** about the potential usefulness of ePortfolios?

Stakeholder: Alumni



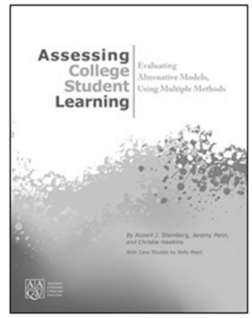
Informing Assessment of Student Learning

- How do ePortfolios and their artifacts inform assessment of student learning?
- What <u>evidence</u> is needed for learners to document their achievements and competencies?

Models of Assessing College Student Learning

(Sternberg, Penn, & Hawkins, 2011)

- Standardized Instruments and Inventories
- Indirect Measures and Measures of Engagement
- Portfolios and Other Performance-Based Assessments
- Locally Designed Tests and Inventories



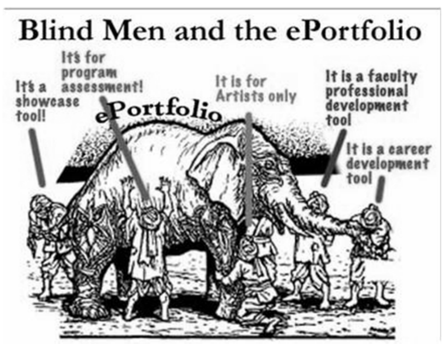


Image credit: Alan Levine
http://learnonline.canberra.edu.au/portfolio/view/view.php?id=2791
With thanks to Cathy Buyarski (IUPUI)

http://learningcsus.myefolio.com/COSABASE/Citizen

Logistical Details for SLCC QL Assessment

- Sampled 100 ePortfolios evaluated by 2-person faculty team (math & humanities)
- Used rubric to analyze the collection of Quantitative Literacy assignments in ePortfolios on 3 indices:
  1. Interpretation
  2. Manipulation
  3. Communication

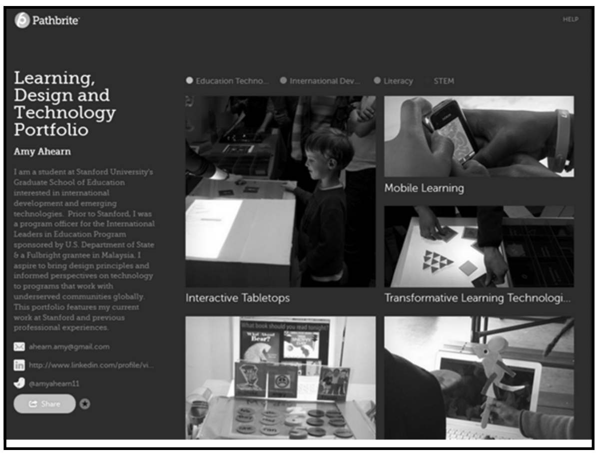
Quantitative Literacy Rubric*

Hubert & Lewis (2013) - SLCC

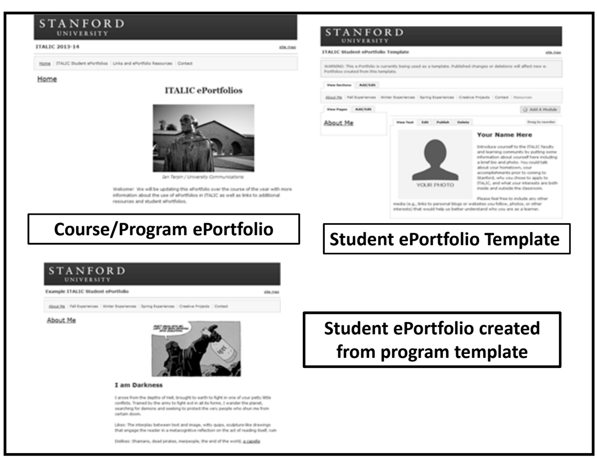
	Exceeds Expectations (4)	Meets Expectations (3)	Below Expectations (2)	Well Below Expectations (1)
Interpretation *Ability to explain information presented to the student in the form of equations, graphs, diagrams, tables, words, etc.* *Total # Assignments______* *Mean Score__________*	Provides accurate explanations of information presented in mathematical forms. Makes appropriate inferences based on that information. # of Assignments________	Provides accurate explanations of information presented in mathematical forms. # of Assignments________	Provides somewhat accurate explanations of information presented in mathematical forms, but occasionally makes minor errors related to computations or units. # of Assignments________	Attempts to explain information presented in mathematical forms, but draws incorrect conclusions about what the information means. # of Assignments________

Using ePortfolio Tools and Technologies

Which ePortfolio features will support the collection of evidence that allows learners to document and demonstrate their learning?



https://stonybrook.digication.com/biodesign_group_5/need



Evaluating the Impact of ePortfolios

- How will you evaluate the impact of your ePortfolio project?
- How will you define success for you? Your students? Your faculty? Your institution?
- What constitutes evidence of YOUR success?

Defining "Success"

(Venezsky, 2001)

Imagine that your ePortfolio project is completed and that it succeeded in all of its goals. You are to appear tomorrow at a press conference to explain what you have accomplished. Write a press release to distribute at this meeting

http://c2l.mcnrc.org/

Examples of Quantitative Evidence of Success

(Eynon, Gambino, Török, 2012)

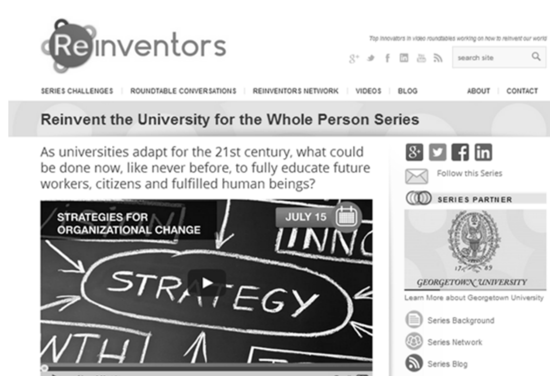
Increase in GPA

- At Manhattanville College, the average GPA of ePortfolio pilot students was 3.097 vs. 2.771 for students in a comparable, non-ePortfolio cohort.

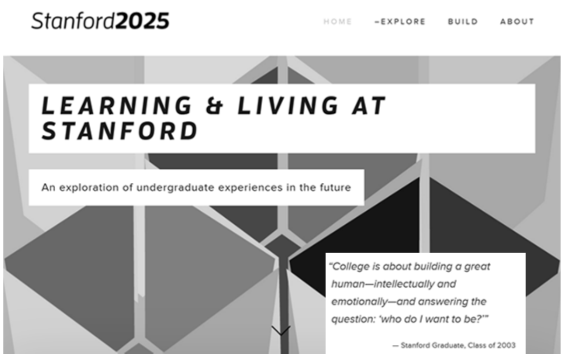
Higher Retention Rates

- At IUPUI, the one year fall-to-fall retention rate for students who complete an ePortfolio (80%) was significantly higher than for students who did not (72%).

Why ePortfolios?
Why now?



http://reinventors.net/series/reinvent-university/



http://www.stanford2025.com/
http://www.stanford2025.com/axis-flip

Working Together: eTranscript & ePortfolio

Enhanced Transcript		**Electronic Portfolio**
Official academic information maintained and certified by institution • Course Descriptions • Faculty Profiles • eDissertations • Grades / Grading Keys • eDiploma • Learning Objectives	⟺	Greater breadth of "unofficial" information maintained and personalized by student • Study Abroad Experience • Individual Course Papers • Internships • Lab Research • Service to the Community • Certificates of Completion

Scholarship Record

SC: **Manipulate a system of symbols logically and consistently so as to derive or prove new results of particular interest or utility**

- Introduction to Statistical Methods (Postcalculus) for Social Scientists. *Instructor(s): McKeon, S.* (ECON 102A)
  Probabilistic modeling and statistical techniques relevant for economics. Concepts include: probability trees, conditional ... *see more*
- *Applied Quantitative Reasoning Requirement Satisfied*

SC: **Study complex processes or systems using theoretical models to predict their outcomes**

- Predicting Volcanic Eruptions. *Instructor(s): Sharf, R.* (GEOPHYS 20N)
  Preference to sophomores. The physics and chemistry of volcanic processes and modern methods of volcano monitoring. ... *see more*
- *Applied Quantitative Reasoning Requirement Satisfied*

SC: **Solve equations or optimization problems through translation to a standardized formalism.**

- Riding the Data Wave. *Instructor(s): Sabatti, C.* (STATS 48N)
  Imagine collecting a bit of your saliva and sending it in to one of the personalized genomics company: for very little money ... *see more*
- *Aesthetics and Interpretive Inquiry Requirement Satisfied*

SC: **Explore their own potential to produce original creative projects**

- Introduction to Animation. *Instructor(s): Edmark, J.* (ARTSTUDI 167)
  Projects in animation techniques including flipbook, cutout/collage, stop-motion such as claymation, pixilation, and puppet ... *see more*
- *Creative Expression Requirement Satisfied*

Formal Reasoning

manipulate a system of symbols logically and consistently so as to derive or prove new results of particular interest or utility.

- PHIL 150 : Basic Concepts in Mathematical Logic (PHIL 250)
- PHIL 151 : First-Order Logic (PHIL 251)
- PHIL 154 : Modal Logic (PHIL 254)
- PHIL 166 : Probability: Ten Great Ideas About Chance (PHIL 266, STATS 167, STATS 267)

solve equations or optimization problems through translation to a standardized formalism.

- MATH 51 : Linear Algebra and Differential Calculus of Several Variables
- PHIL 150 : Basic Concepts in Mathematical Logic (PHIL 250)
- PHIL 151 : First-Order Logic (PHIL 251)
- PHIL 154 : Modal Logic (PHIL 254)

study complex processes or systems using theoretical models to predict their outcomes.

- CS 107 : Computer Organization and Systems
- PHIL 150 : Basic Concepts in Mathematical Logic (PHIL 250)
- PHIL 151 : First-Order Logic (PHIL 251)
- PHIL 154 : Modal Logic (PHIL 254)
- PHIL 166 : Probability: Ten Great Ideas About Chance (PHIL 266, STATS 167, STATS 267)

use deductive reasoning correctly through the study of particular examples in an area of interest at the collegiate level.

- ECON 50 : Economic Analysis I
- PHIL 150 : Basic Concepts in Mathematical Logic (PHIL 250)
- PHIL 151 : First-Order Logic (PHIL 251)
- PHIL 154 : Modal Logic (PHIL 254)
- PHIL 166 : Probability: Ten Great Ideas About Chance (PHIL 266, STATS 167, STATS 267)

Formal Reasoning

solve equations or optimization problems through translation to a standardized formalism.

- MATH 42 : Calculus (Accelerated)
- MATH 41 : Calculus (accelerated)

use deductive reasoning correctly through the study of particular examples in an area of interest at the collegiate level.

- CS 106A : Programming Methodology (ENGR 70A)

Introduction to the engineering of computer applications emphasizing modern software engineering principles: object-oriented design, decomposition, encapsulation, abstraction, and testing. Uses the Java programming language. Emphasis is on good programming style and the built-in facilities of the Java language. No prior programming experience required. Summer quarter enrollment is limited and requires an application.

Socia

The c ring phenomenon in huma s, societies, and indivi d legitimate, what the reacti pped.

- THINK 12 : Century of Violence

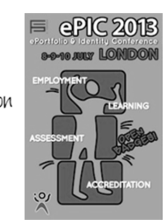
National & International ePortfolio Initiatives

CRA CENTRE FOR RECORDING ACHIEVEMEN

EPAC electronic portfolio action & communication

IJeP International Journal of ePortfolio

AAEEBL The Association for Authentic, Experiential and Evidence-Based Learning



ePortfolios Australia

AAC&U Association of American Colleges and Universities

Association of American Colleges and Universities

A VOICE AND A FORCE FOR LIBERAL EDUCATION IN THE 21ST CENTURY

2015 FORUM ON DIGITAL LEARNING AND E-PORTFOLIOS

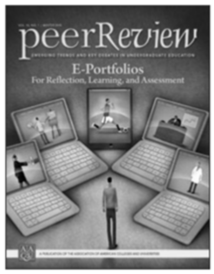
GLOBAL POSITIONING SYSTEMS:
The Digital Age and E-Portfolios

Saturday, January 24, 2015
Held in conjunction with AAC&U's 2015 Annual Meeting
Grand Hyatt Hotel / Washington, DC

The Forum on Digital Learning and E-Portfolios is jointly sponsored by AAC&U's project, VALUE: Valid Assessment of Learning in Undergraduate Education; and the Association for Authentic, Experiential and Evidence-Based Learning (AAEEBL), the association of e-portfolio professionals.

VALUE
Valid Assessment of Learning in Undergraduate Education

AAEEBL



Thank you!

Helen L. Chen, Ph.D.
Director of ePortfolio Initiatives
Office of the Registrar
Research Scientist, Designing Education Lab
hlchen@stanford.edu

EPAC Community of Practice
http://epac.pbworks.com/

Sketch... **who are the stakeholders for your ePortfolio project.**

Artifacts/Evidence in a student ePortfolio

WASC Senior College and University Commission | EDUCATIONAL PROGRAMS

Plenary

Developing a Campus Culture that Embraces Outcomes Assessment

J. Lindholm

Developing a Campus Culture that Embraces Assessment of Learning in Majors

Jennifer A. Lindholm

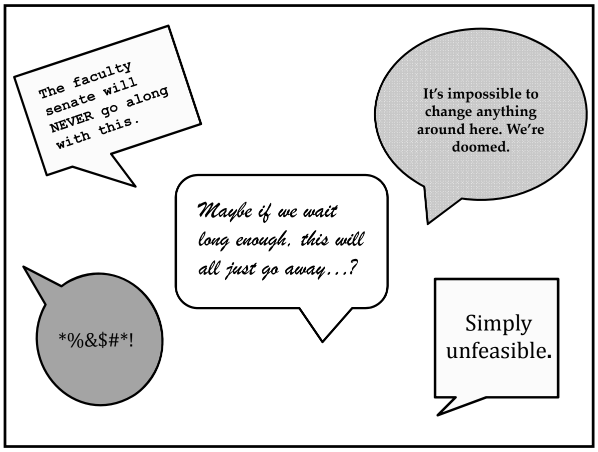
Culture

- Shared values, assumptions, beliefs, and ideologies that members have about their organization and its work

- Embedded patterns of organizational behavior

Autonomy

Accountability



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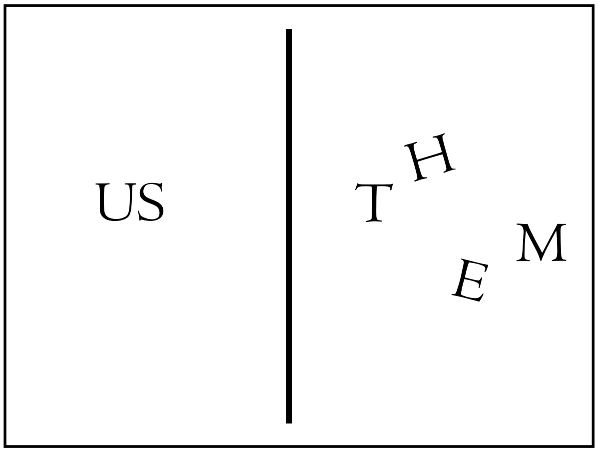
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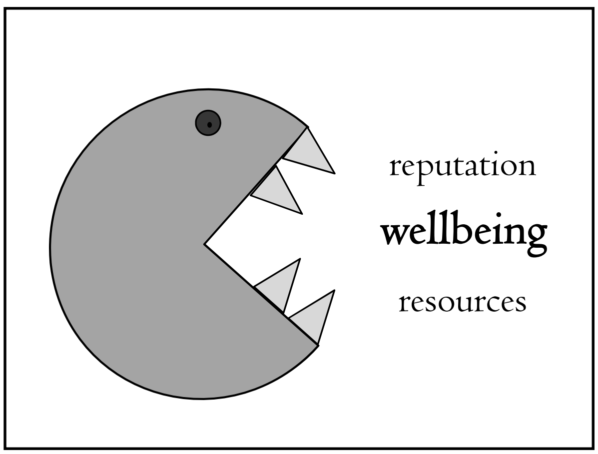
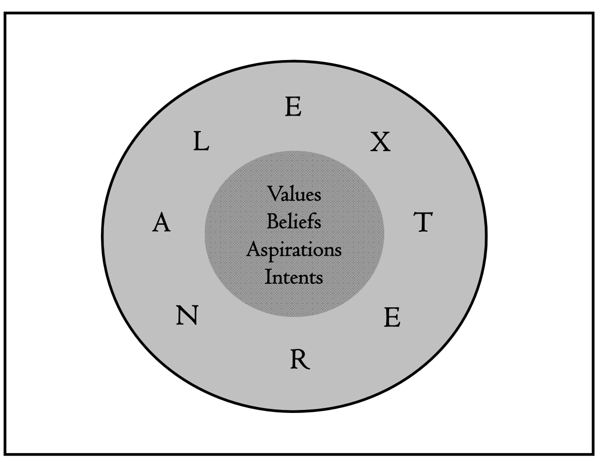
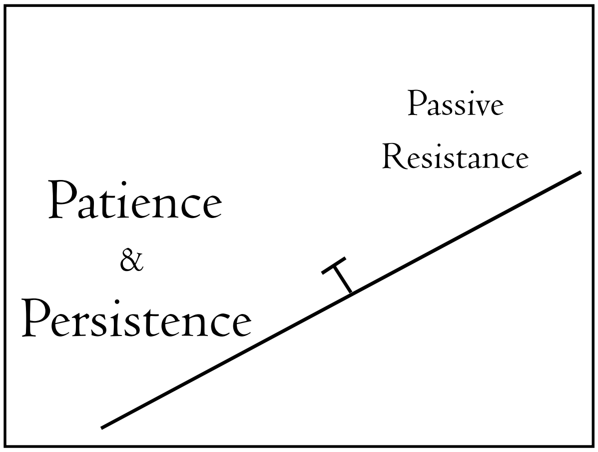
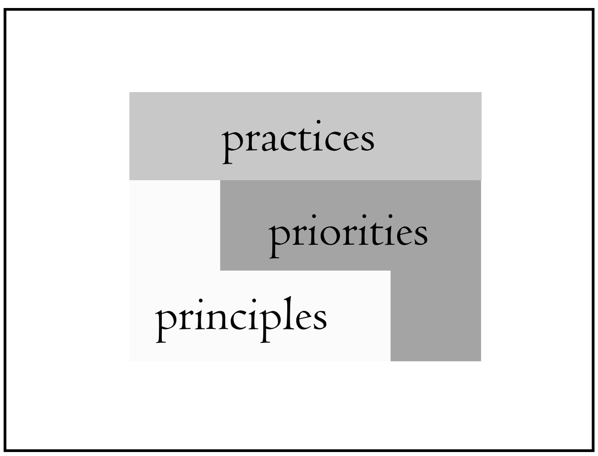
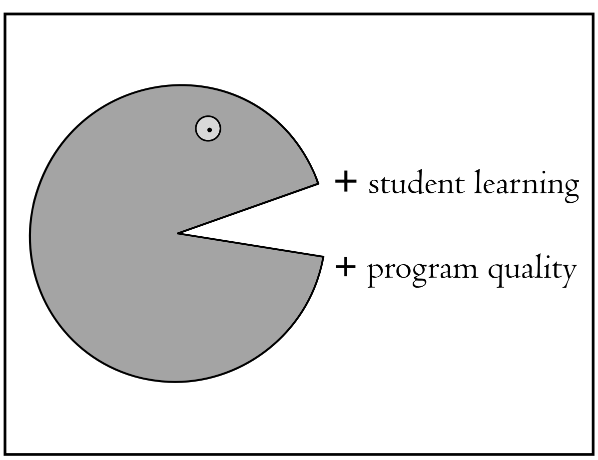
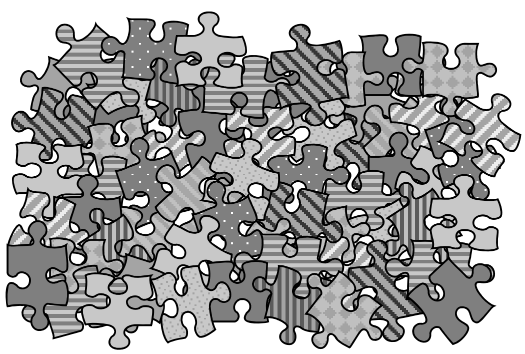

reputation
wellbeing
resources

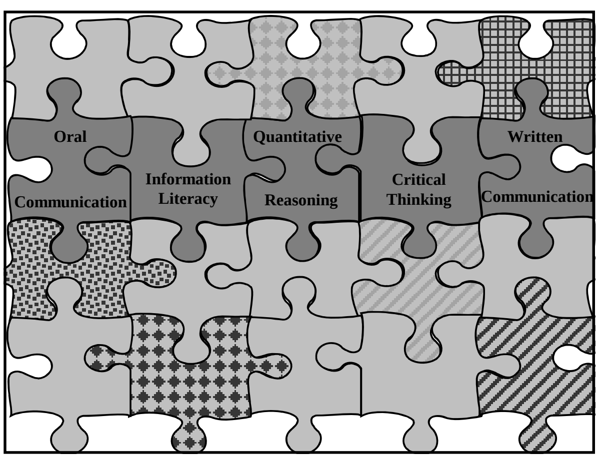

EXTERNAL
Values
Beliefs
Aspirations
Intents


Passive
Resistance
Patience
&
Persistence


practices
priorities
principles


+ student learning
+ program quality




Oral
Communication
Information
Literacy
Quantitative
Reasoning
Critical
Thinking
Written
Communication

○ signature assignment ○ portfolio ○

○ comprehensive exam ○

○ capstone experience ○ research project ○

○ creative performance ○

○ standardized test ○ internship ○

~~ONESIZE~~

Meaningful

&

Manageable

Sustainable

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HOW

Commitment

Compliance

Communication

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Breakout 4

Student Learning Assessment and Academic Program Review

J. Lindholm

Student Learning Assessment
&
Academic Program Review

Jennifer A. Lindholm

Academic Program Review Goals

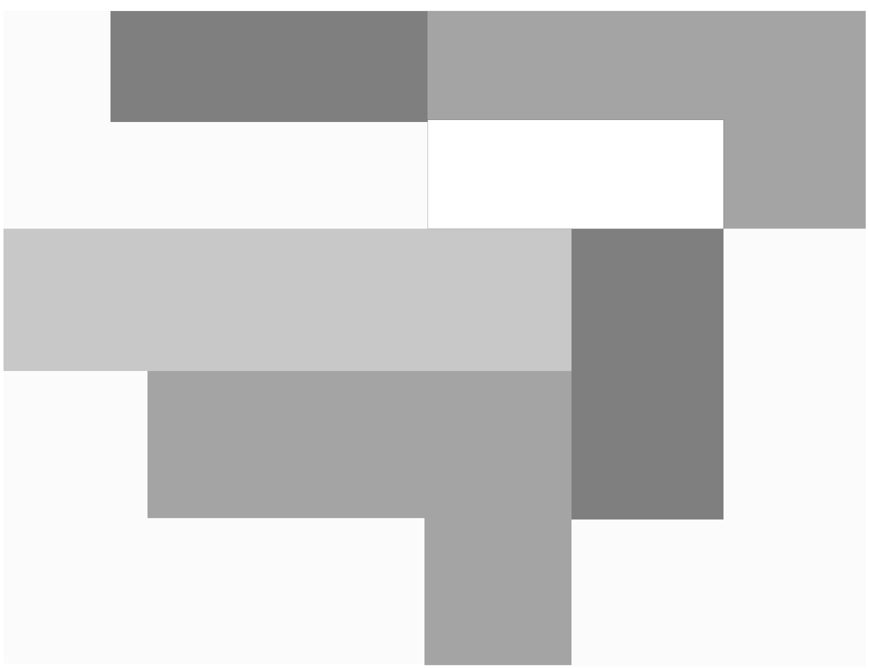
Maintain and strengthen the quality of undergraduate and graduate degree programs by:

- recognizing strengths and achievements
- promoting goal setting and planning
- identifying areas in need of attention

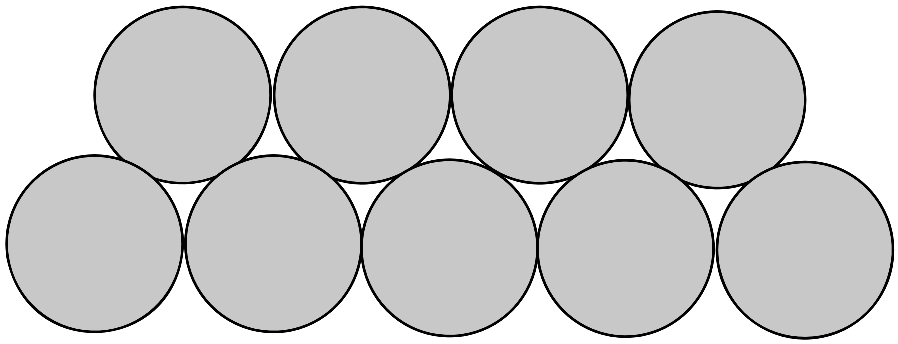
Embedding "Outcomes" Interests in Program Review

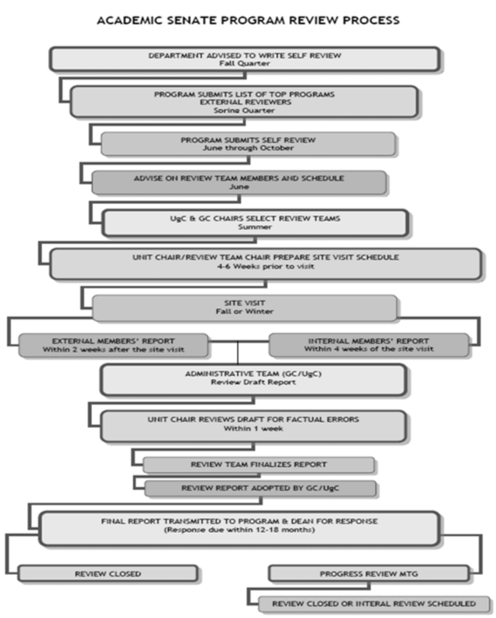
- promotes shared understanding and ownership of accreditation-related expectations and commitments

- supports creating and sustaining a culture that embraces assessment as part of routine practice



Program Review "Best Practices"





S
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E

UCLA Academic Senate: http://www.senate.ucla.edu/programreview/documents/FlowchartProcess_2_.pdf

Self-Study Report Guidelines: Undergraduate Programs

Provide an overview of the goals, rationale, structure, and effectiveness of your undergraduate programs, providing evidence and support as appropriate.

- What aspects of undergraduate education do you do well?
- What areas do you feel need to be strengthened?
- What changes do you anticipate in the future?
- How does your program compare to other programs, departments, or units within UCLA and in your discipline at other universities?

Self-Study Report Guidelines: Undergraduate Programs

In compliance with federal expectations that colleges and universities document evidence of student learning (beyond grades earned in individual courses), and in keeping with UCLA's accreditation-related commitments, please be sure to:

- include the articulated learning objectives for each of your major programs, noting any changes introduced since the last program review;
- describe efforts made to evaluate achievement of those learning objectives; and
- summarize key findings and describe any changes you have implemented in your major degree program(s) as a result of your evaluation efforts

Self-Study Report Guidelines: Undergraduate Programs

Please also address, as appropriate, the following:

- your department contributions to broader undergraduate education at UCLA
- time-to-degree statistics for your undergraduate majors
- the role of online courses in your undergraduate program, any impact on student experience, and any efforts to assess the effectiveness of online course delivery
- your department's summer session course offerings, including the balance between academic year and summer offerings of upper division courses
- how issues of diversity are included in your undergraduate curriculum

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Breakout 5

Designing a Mature Quantitative Reasoning Assessment Plan for the Major

D. Sundre

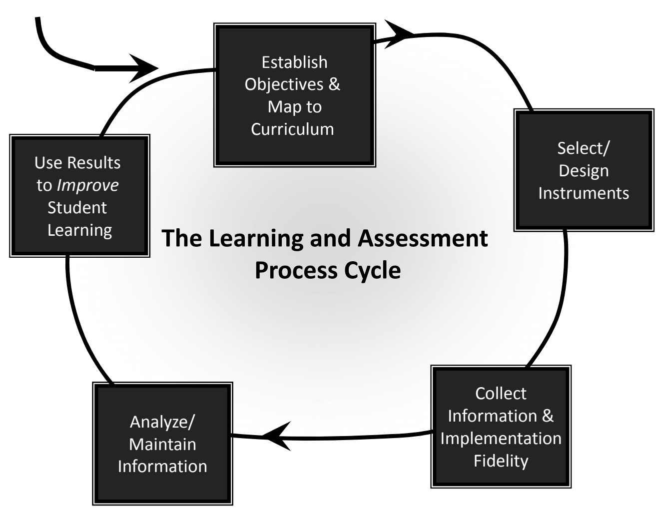
Designing a Mature Quantitative Reasoning Assessment Plan

James Madison University

Donna L. Sundre,
Executive Director, CARS

www.jmu.edu/assessment

What is Assessment?



THE CENTER FOR ASSESSMENT & RESEARCH STUDIES

Why Engage in Assessment?

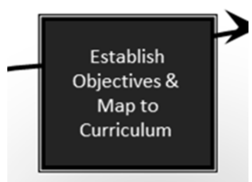
Table 1.1. What Is Assessment

Assessment is the ongoing process of:
Establishing clear, measurable expected outcomes of student learning
Ensuring that students have sufficient opportunities to achieve those outcomes
Systematically gathering, analyzing, and interpreting evidence to determine how well student learning matches our expectations
Using the resulting information to understand and improve student learning

Suskie, L. (2009). Assessing student learning: A Common sense guide, (2nd ed.). Bolton, MA: Anker Publishing Company Inc.

THE CENTER FOR ASSESSMENT & RESEARCH STUDIES

A closer look into the Cycle



- Specific statements that specify an observable behavior
  - Must be measurable (easier said than done sometimes)
- Clearly conveys the impact a program is supposed to have on participants
- The ABC's
  - A: Audience – For whom the objective is intended (learners, students)
  - B: Behavior – Specific observable action the learner is expected to exhibit
  - C: Conditions – Relevant factors affecting the behavior/performance
- After establishing objectives, they must be mapped to curriculum or programming

Identifying Objectives

Examples from Biology

- Discriminate between association and causation, and identify the types of evidence used to establish causation
- Obtain, organize, analyze and interpret data
- Evaluate a statement, hypothesis, or claim using different kinds of evidence, including qualitative and quantitative observations and experimental results
- Use mathematics to understand and analyze biological phenomena.

Identifying Objectives

Examples from Physics and Chemistry

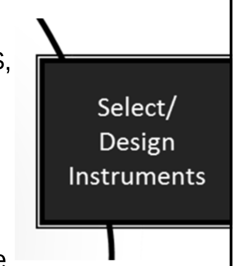
- Gain an understanding of the basic principles and the experimental basis of the various fields of physics and the logical relationships of the various fields.
- Become capable problem solvers using techniques that require mathematical skills, conceptual and mathematical models, order-of-magnitude estimates and an understanding of limiting cases.
- Students will be able to solve quantitative and conceptual problems in core Content Knowledge areas of the chemical sciences.

Mapping Objectives to Curriculu

Course	Goal 1		Goal 2	Goal 3		
	1.1	1.2	2.1	3.1	3.2	3.3
105	X	X	X	X		
ASTR 120	X	X	X			
ASTR 121	X	X	X	X		
125	X	X	X	X	X	X
126	X	X	X	X	X	X
140	X	X	X	X	X	X
150	X	X	X	X	X	X

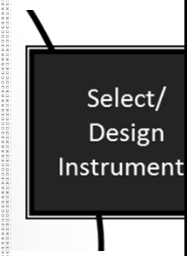
A closer look into the Cycle

- Different kinds of measurement tools
  - Cognitive (MC, fill in the blank, essay)
  - Non-cognitive (Likert)
  - Performance Assessment
  - **Commercial**- copyrighted, available for $$$$, used in practice
  - **Non-commercial** – available for free, used in research
- **The key is to have a <u>MATCH</u> between the objective AND measure**
  - <u>*Learning* objectives</u> usually call for some type of *cognitive test*, where there is a degree of “correctness” (right or wrong, scored using a rubric)
  - <u>*Developmental* objectives</u> usually call for some type of *non-cognitive test* focused on level or amount of some construct (anxiety, self efficacy, help seeking)



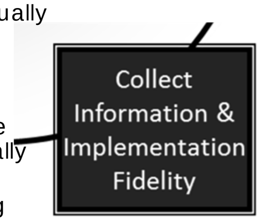
A closer look into the Cycle

	Advantages	Disadvantages
Existing	• Easy and convenient • Most instrument development work is done! • Efficient – can use the results right away • Accumulate validity evidence for the scores • Can compare findings to prior research • Can tweak the existing measure to fit the specific need	• Less than ideal alignment with the objective • Insufficient validity and reliability evidence (no factor analytic studies, different populations) • Cost • Item-level data • Scoring
New	• High fidelity of assessment (potentially perfect match) • A measure created for a new construct	• Test development is a very long and involved process! • Need validity evidence • Cannot compare results



A closer look into the Cycle

- Lots of Logistics!
  - Will instrument be administered online (CBT) or via paper and pencil?
  - Who administers the instrument and under what conditions?
  - How will students be motivated to complete the instrument?
- Beyond just collecting information, we need to know if the intended programming was actually implemented and:
  - Were all the specific features of the program actually implemented?
  - Did students have *opportunity to learn*?
  - How well was the program implemented?
  - Did each component of programming last for the intended duration and how many students actually attended?
  - How responsive or engaged were students during programming



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A closer look into the Cycle

- Beyond just collecting information, we need to know if the intended programming was actually implemented and:

Specific program features, what are students doing to help them meet the objective	**Program Differentiation**
Were all the specific features of the program actually implemented? Did students have opportunity to learn?	**Adherence**
How well was the program implemented?	**Quality**
Did each component of programming last for the intended duration and how many students actually attended?	**Exposure**
How responsive or engaged were students during programming	**Responsiveness**

Collect Information & Implementation Fidelity

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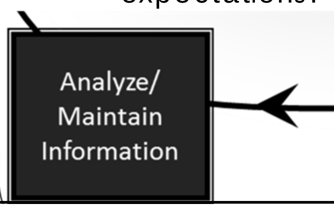
Example from Biology

Objectives:	Method(s) to Assess:
1. Discriminate between association & causation	NW-9 Items: 3, 34, 35, 3 37, 53, 60-63, 79-85
2. Formulate a hypothesis & identify relevant variables	NW-9 Items:18, 34-37, 41-42, 47-50; ASI Items 1-7
3. Design and execute experiments to test hypothesis	NW-9 Items: 9-23, 48-50 67-78 ASI Items: 8-12
4. Obtain data	ASI Items: 13-19

A closer look into the Cycle

Four General Analytic Questions:

- **Relationships**: What is the relationship between assessment outcomes and program components (i.e., course grades, peer ratings)?
- **Differences**: Do students learn or develop more if they participate in a program compared to students who did not participate?
- **Change**: Do students change over time?
- **Competency**: Do students meet program expectations?



A closer look into the Cycle

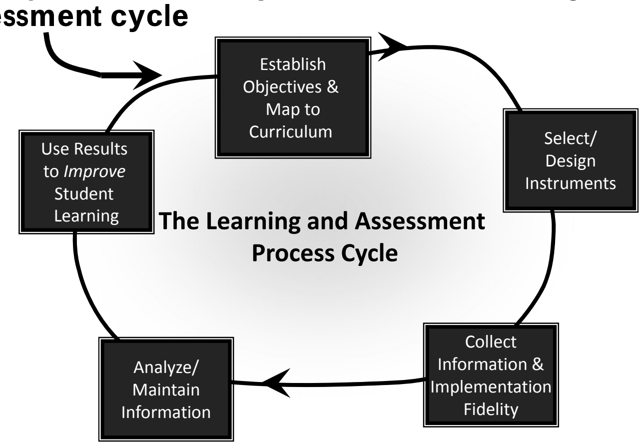
- Last, but most important, step in the cycle
- Often referred to as "true closing the loop"
- Requires institutions to "**go beyond collecting evidence of student learnin to actually using the results effectively** (Blaich & Wise, 2011)
  - Assess
  - Make changes (program, pedagogy, curriculum, etc.
  - Re-assess to see if those changes actually improved student learning outcomes

A closer look into the Cycle

- In general, institutions seem to be good a collecting data
- However, not so good at using the results of data collection to improve student learning
  - Why?
  - Reports get filed away and forgotten
  - Belief that the report itself is enough to prompt and enact action
    - …False
  - Requires collaboration and conversation
    - "…but the communication must at some point move from talking about the data to talking about, and then enacting, change (Blaich & Wise, 2011)

Summary

- **Identify the basic components of the learning and assessment cycle**

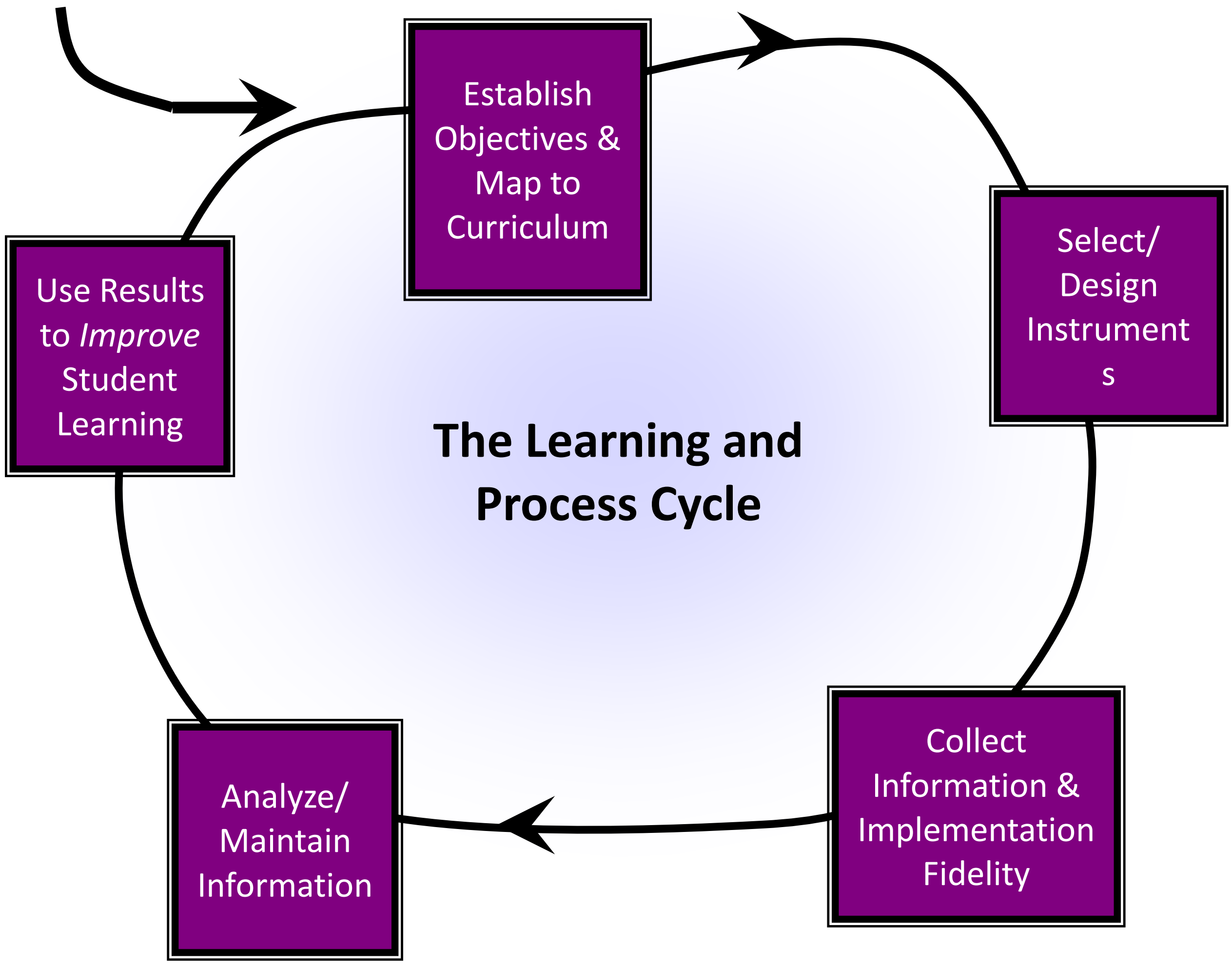


Summary

- **Articulate the purpose of assessment**
- Assessment can have multiple purposes:
  - Accreditation
  - Accountability
  - Resource allocation
- **Higher education assessment should <u>ALWAYS</u> have one driving purpose:**
  - **TO *IMPROVE* STUDENT LEARNING**
    - **Assess**
    - **Make changes**
    - **Re-assess to see if those changes actually improved student learning outcomes**

Questions?

The Learning and Assessment Cycle



GENERAL ASSESSMENT PLAN

Objectives:	Courses and Co-Curricular Opportunities Where the Objective is Addressed:

GENERAL ASSESSMENT PLAN

Objectives:	Method(s) to Assess Objective:

GENERAL ASSESSMENT PLAN

Objectives:	Items to Assess Objective:

New Item Template

Part 1

Stem

Correct Answer

Distractor 1

Distractor 2

Distractor 3

Preferred Order of Options on Test Form

Part 2

Cluster Affiliation

Objective To Which Item Is Keyed

Author

Date Created

Date Revised

Brief Justification Of Correct Response

Brief Explanation Of Errors Within Distractors

Associated Media/Stimulus Material

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Breakout 6

A Framework for Leading Campus-Wide Change Initiatives

S. Elrod

The Keck/PKAL Scientific Framework for Strategic Change in STEM Education:
A Workbook for Campus Teams to Promote Institutional Change

Susan Elrod and Adrianna Kezar

Executive Summary

This workbook provides campus teams and leaders practical guidance on how to apply the newly developed *Scientific Framework for Strategic Change in STEM Education* for planning, implementing and sustaining reforms that improve student learning and success, particularly for students who come from underrepresented minority (URM) populations. Many change efforts have been started but few have reached the transformational level of entire programs, departments, or colleges in the STEM disciplines. The Framework begins with the establishment of a vision and goals for the change project. After this step, then the Framework guides teams through an analysis phase to gather data and collect information about the current STEM learning and student success landscape. This analysis leads to the identification of specific campus challenges defined by the data and couched in the context, mission, and priorities of the campus. These challenges help teams establish the outcomes of the change project and lead them to choose, implement and evaluate specific strategies that will address the challenges and improve STEM student learning and success. Any change process is dynamic and nonlinear so this Framework is described as a flow, much like a river where there are multiple points of entry (and exit!) as well as obstacles that might be encountered along the way that create eddies in the flow. This workbook is a compilation of tools provided in the more detailed Framework Guidebook (Elrod and Kezar, in press). The specific tools are as follows:

- Key questions, timeline considerations and challenge alerts for teams to consider at each phase of the process.
- Resources to help teams determine how to get started, conduct data analyses, avoid common pitfalls, build effective teams, address leadership, and sustain change.
- Example interventions and highlights from campus case studies.
- A readiness survey will also help teams determine whether they are prepared to move forward with implementation of their chosen strategies and interventions.
- A rubric to help campus teams gauge their progress in the Framework phases.

While this Framework was developed with STEM education reform in mind, it can be applied more generally for any campus-wide or institutional change project. This handout provides information about the Framework in the context of any type of campus initiative.

Acknowledgements

The authors would like to acknowledge the generous support of the W.M. Keck Foundation and the contributions by the campuses that participated in the project:

- California State University, East Bay
- California State University, Fullerton
- California State University, Long Beach
- California State University, Los Angeles
- San Diego State University
- San Francisco State University
- The W.M. Keck Science Department of Claremont McKenna, Pitzer and Scripps Colleges
- University of San Diego
- University of La Verne
- The California State University Chancellor's Office
- University of California, Davis

They should be applauded for their willingness to dive into this project, explore new territory and build new models with us. Their success is a result of intense campus passion and expertise as well as tenacity and persistence! We are also grateful for the support of Project Kaleidoscope and AAC&U for sponsoring the project, providing staff support and opportunities for presentation at national meetings.

I. Introduction

A. Background

For the past 20 years, countless reports have been issued calling for change and reform of undergraduate education to improve student learning, persistence and graduation rates for students in STEM; however, by many measures recommendations in these reports have not been widely implemented (Seymour 2002; Handelsman, et al. 2004; Fairweather 2008; Borrego, Froyd and Hall 2010). Aspirational student success goals in STEM have been set most recently by the President's Office of Science and Technology (PCAST) recent report, entitled Engage To Excel: Producing One Million Additional College Graduates in Science, Engineering, Technology and Mathematics (2011). The report states that STEM graduation rates will have to increase annually by 34% to meet this goal, and the greatest opportunity for improvement is in the graduation rates of under-represented minority (URM) students since their graduation rates lag behind those of majority students. More recent reports reiterate the need to focus on creating more student-centered learning environments that are built on a foundation of conceptual learning goals and use of the most effective research-based teaching, learning and assessment strategies (AAAS, 2012; AAMC/HHMI, 2012). The meta analysis that Scott Freeman and his colleagues conducted of recent science education research papers and conclusively confirms that by using active learning strategies as opposed to traditional lecture, student exam scores increase and failure rates drop dramatically (Freeman et al, 2014). Moreover, the increasingly interdisciplinary nature of the 21st century and the global challenges our society faces require that students be engaged in learning that will prepare them to address and solve these problems (National Academies 2009, 2010a, 2011, and 2012). Still other research and program development has shown that changing the learning environment toward more interactive and engaging teaching methods is only one factor that leads to improved student success.

In addition to improvements in pedagogy and curriculum, STEM leaders are also recognizing the multifaceted changes needed in order to create student success. Student advising, faculty professional development, student research mentoring, academic support programs, clear STEM-focused institutional articulation agreements, external partnerships with business and industry related to internships and other research experiences, among other critical areas are often overlooked within reform efforts and have been identified as central to student success. These programs are particularly important for students who are typically underrepresented in STEM disciplines, the group with the largest potential to contribute to the PCAST report's lofty degree production goals. These multifaceted changes that include partnerships with student affairs and other support programs as well as entities outside the institution suggests an institutional rather than departmental approach to change. Also key instructional and curricular reforms also need support from the institution in terms of altering promotion and tenure and reward structures or getting enough support for professional development. There is gaining recognition that reform in STEM is an institutional imperative rather than only a departmental one. For example, the Meyerhoff Scholars Program at the University of Maryland, Baltimore County combines specific academic, social and research support interventions that have resulted in dramatic improvements in graduation of minority STEM students (Lee and Harmon, 2013). In addition, research suggests that changes made to improve student engagement, such as implementation of high impact practices, has a benefit for all students, but has a greater impact on URM students (see for example, Beichner, 2008; Kuh and O'Donnell, 2013; Finley and McNair, 2013). The

Center for Urban Education's Equity Scorecard (http://cue.usc.edu/our_tools/the_equity_scorecard.html) provides a specific approach – both qualitative and quantitative - for addressing URM equity issues across all disciplines at the institutional level.

Thus, approaches to change in STEM higher education require a systemic and comprehensive approach that engages all levels of the institution, from department faculty to student affairs professionals to deans, provosts and presidents. As a result, this framework focuses on institutional change in the way that STEM change agents can facilitate this particular type of reform. In fact, one of the major contributions of this report is to help STEM leaders recognize and leverage institutional resources needed for STEM student success. It was informed by research and developed in collaboration with eleven campus teams from both public and private universities working on STEM education change projects with the generous support of the W.M. Keck Foundation over a three-year project period.

B. Fostering Change

In order to make progress toward more institutional reform efforts, a comprehensive, ***Scientific Framework for Strategic Change in STEM Education*** has been developed. This Framework is geared toward helping campus leaders plan, implement and assess systemic change strategies that improve recruitment, access, retention, learning, and completion for all students in all STEM disciplines. This includes the breadth of ways that students engage in STEM learning on our campuses, from students in STEM majors to those taking science and mathematics general education program requirements, meeting quantitative reasoning requirements, and taking science or mathematics prerequisite courses required for applied majors such as agriculture or those in the health professions.

As noted above, most prior initiatives or reports have been aimed at altering individual faculty or departmental activities, and there is little research that has helped leaders to understand the various interventions that might be implemented that extend beyond departments creating an institutional vision for STEM reform. In addition, earlier efforts have not addressed the policies and practices at the institutional level that often hinder reforms or can be leveraged to enable greater changes. For example, a very common problem is a lack of faculty workload adjustments to provide them with the time to devote to redesigning courses or participating in the required professional development.

> *"New insights gained from the ongoing interactions have contributed to an iterative design process and to the non-linear nature of our work. The constant need and desire to adjust plans and actions based on new knowledge and insights acquired makes it challenging to develop a single plan."*
> - CSU East Bay

There are many different approaches to creating change within colleges and universities. A typical model is often of strategic planning and this Framework includes some of the practices often included in strategic planning such as vision setting, identifying benchmarks, and conducting a landscape analysis. However, our approach to change is based on practices of organizational learning. Within this approach to change, information gathering and data analysis play a central role in helping individuals to identify directions and appropriate interventions for making strategic forward progress. Participants in any organizational learning planning process foreground the data, reflection, dialogue, and non-hierarchical teams learning and developing innovative approaches. This means having campus teams look at data related to student success in order to determine the specific challenges and problems and to orient themselves towards a vision for change. But an organizational learning model also focuses on learning throughout the change process.

The Framework is focused on facilitating organizational learning, but it also incorporates key ideas from other research on change, such as the need to address politics, developing buy-in and a shared vision, understanding the power of organizational culture, and helping campus leaders unearth underlying assumptions and values that might create resistance to change. It should be noted that almost all these processes – organizational learning, addressing politics, creating a shared vision and unearthing cultural assumptions – were extremely hard for STEM leaders in the project to embrace. These processes are often messy and non linear. However, strategic planning approaches that are linear and less messy were often preferred by the leaders we worked with, which suggests that teams are not naturally inclined to use the strategies that work to create change. We describe this challenge in more detail later under implicit theories of change (Kezar, Gehrke and Elrod, in preparation).

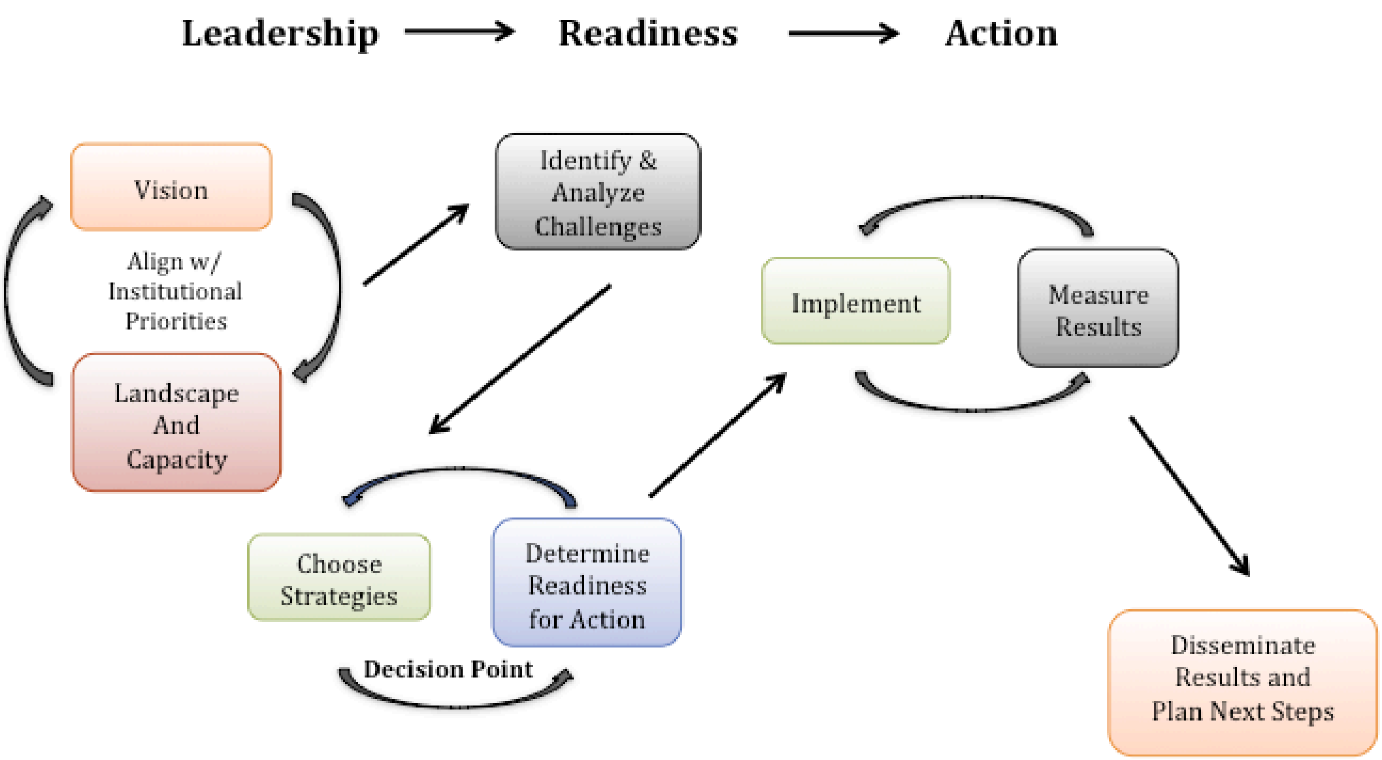
The Framework, described below, articulates both the practical steps and logistics of the work of STEM reform as well as the key phases for leading, supporting, implementing and sustaining program interventions that result in improved student learning and success, particularly for under-represented minority (URM) students. Most campuses in the project had URM student success as a primary component of their project goals; however, they took different approaches to achieve improved outcomes for these students based on various factors identified in the Framework process (e.g., leverage points, existing expertise, capacity, etc.). While it was developed explicitly for STEM reform projects at the institutional level, we believe it has utility for any systemic reform project.

II. Keck/PKAL Scientific Framework for Strategic Change in STEM Education

A. The Framework

The Framework process is illustrated as a river to illustrate the dynamic, flowing nature of change (Figure 1). It begins at the upper left and proceeds toward the lower right with the colored boxes representing the practical steps that need to occur along the way. Leadership is critical for starting the process. The process also requires a significant readiness assessment component to gauge campus climate, capacity for change and resources required for program development. And, finally the process leads to action of the planned strategies that leads to desired results.

Figure 1. The Framework



A river analogy is most apt, not only because of the flowing nature of a river, but because a river is a dynamic, changing structure. The flow (change process) encounters obstacles (challenges presented by certain aspects of the change process) that may result in a eddy where the flow circles around the obstacle until it can break free. Travelers on the river may enter at various points or put out at certain locations to rest. New travelers may enter and join a party already on a journey down the river. Indeed, teams working on system change may start at different points, change membership or even stop out for periods of time because other campus priorities emerge, team members take on other duties, campus leadership changes, etc.

The eddies in the Framework flow indicate where effort has a tendency to loop back in an iterative process. For example, in the visioning process, the data landscape analysis informs and refines the vision. It is not a linear, stepwise process, but one that is more dynamic like a flowing river that produces occasional eddies off to the side as it encounters obstacles. The resulting eddy motion is an apt analogy for the circular swirl, or iterative process, that campus teams experience when they encounter resistance, challenges along their path toward reform. They must work through the issue, determine the nature of the challenge and figure out how to get the flow going again in the desired direction. In a “reform eddy” teams “peel out” or pause while the obstacle is investigated and further analyzed before they are able to get out of the circular flow and continue further downstream. Teams may also enter the river at different points, depending on where they are in terms of understanding of the problem, existing expertise, campus leadership capacity, etc. Teams can also swim up or downstream, although the general flow will be ultimately to go downstream toward action and success. Deploying the Framework using these elements can be painful and challenging but it is extremely helpful to envision what you think will work for you and to identify where you are, based on campus context, expertise, leadership, etc. Wherever you start, we believe you must somehow address all the elements at some point or time.

Throughout the flow, leadership is required, readiness must be assessed and, ultimately, action is taken (represented in the upper part of the Framework diagram). Leaders must be identified early in the process. These leaders may be from the central administration, departmental, division, or college. External experts and/or partners may also play a critical early leadership role (board of trustee member, K-12 partner). Early adopters/disrupters who are faculty that are already engaged in course redesign or DBER (discipline-based educational research) or are champions (influential faculty leaders) are common early leaders for change in STEM. These individuals make up important members of an initial team to get the project started. Some resources (particularly time for faculty leaders to devote to planning and initial analysis) are extremely helpful during this phase. Funding from special project funding pools or external grants can seed initial efforts.

There are eight Framework elements:

1. Vision -- The vision represents the direction that the campus is aimed in terms of altering the learning and student experience to support success. We encourage a vision that is clear and shared.

2. Landscape and capacity -- A direction forward is typically best created through an analysis of the existing landscape (internal campus data as well as external trends, research and reports) as well as a review of current capacity to engage in change generally **--** such as history of reform, leadership, and buy-in and ownership among faculty. This stage focuses on the collecting of data and information to conduct analysis.

3. Identify and analyze challenges -- The landscape and capacity information needs to be analyzed in order to identify both challenges and opportunities for the campus. This phase often brings in aspects of both politics and culture that might be sources of both opportunities and challenges.

4. Choose strategies/ interventions/opportunities -- Campuses need to familiarize themselves with a host of strategies or interventions that they might choose from to address the challenges identified. They can examine these strategies in light of the capacity of the campus as well as opportunities identified earlier.

5. Determine readiness for action -- In addition to reviewing the capacity and opportunities, there are key issues that emerge when implementing specific strategies such as resources, workload, institutional commitment, facilities, timeline and other areas that should be reviewed in order to effectively implement the strategy and to ensure that the campus is ready to move forward with that particular strategy. Campuses will be able to identify opportunities, such as a newly established special campus projects fund, a new faculty hire with appropriate expertise, etc. that can be leveraged in support of effective implementation. Besides ensuring that a solid plan for action has been developed, this phase also involves exploring campus politics and culture.

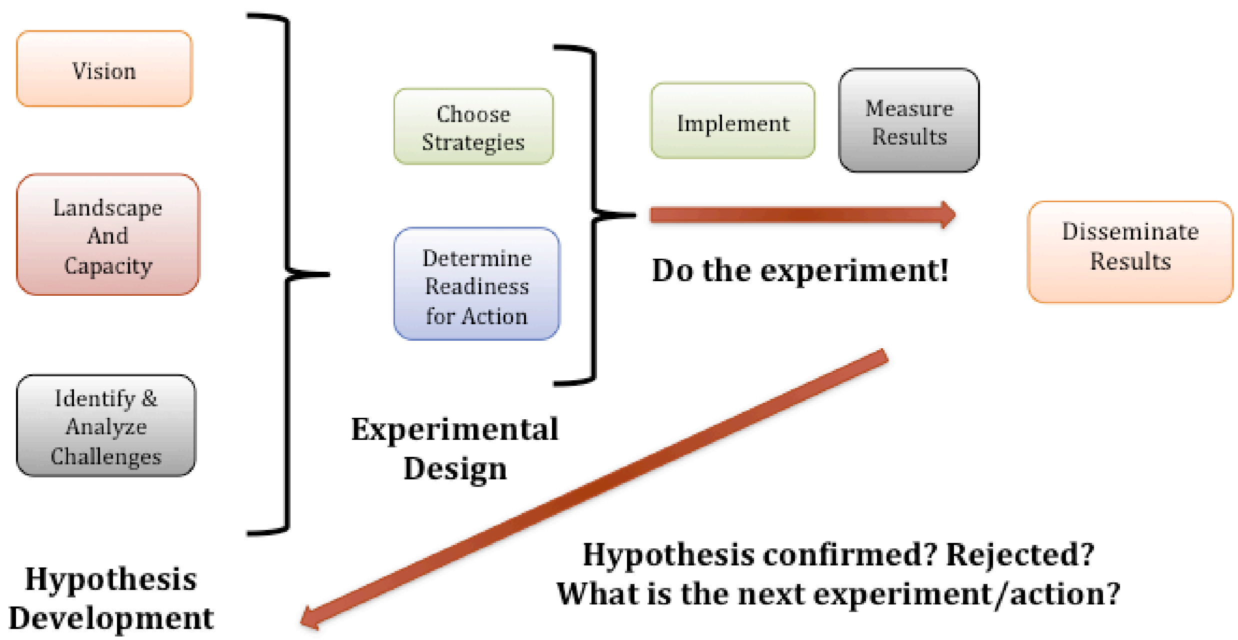
6. Implementation - Implementation involves drafting a plan for putting the intervention or strategies in place. The plan builds off of the ideas from the readiness for action, capacity of the campus, and opportunities identified. All of these will be built into the plan as well as a process for understanding challenges as they emerge. In addition to a well laid out plan, campuses may decide to pilot an initiative first and then consider how to modify and scale it after an initial trial.

7. Measure results -- Campuses will also create an assessment plan to inform whether the intervention is working and ways they can be changed over time to work better.

8. Disseminate and plan next steps – In order to prevent the continued siloization of our work, it is important for campuses to think about dissemination opportunities on campus as well as off campus, either regionally, statewide or nationally. Also, keeping the momentum going will require deliberate planning for next steps.

Figure 2 below represents the Framework elements arranged in the stages of the scientific method. Science faculty may find this version more approachable because it represents the change process in terms of the development of scientific knowledge, from hypothesis development to experimental design and testing. The Framework stages are placed in this context to show the parallels between these two processes. Through our work, we identified that faculty may resonate better at least initially with this representation of the framework. A similar framing has previously been used by Handelsman et al., (2004) and Weiman (2007) to help science faculty see the connections between their disciplinary mindset of discovery and experimentation, and that of educational research and reform. What we found is that one way to orient or approach change often does not work, so we offer this different vantage point that may more strongly resonate.

Figure 2. A Scientific Version of the Framework



B. Steps in the Framework Process

Step 1. Determine where to enter the Framework

It needs to be emphasized that each campus must construct its own "framework" process. Our experience is that this Framework provides a general outline that can be used by individual campuses and customized to help them institutionalize and sustain STEM reform efforts. Individual campus processes vary tremendously, navigating through the framework in very different ways. However, campuses will eventually hit on all of the aspects of the Framework. From our experience with the participating campuses, if a particular area was ignored they found themselves drawn back to that issue because it became a barrier to their forward movement. As a result, most campuses did not move through the framework in a linear fashion. Sometimes it took teams 2 to 3 years to reassess goals and to experience enough roadblocks that they finally returned to the initial steps. When they did, there was a new clarity of purpose. But at the end of the project, each team noted that had they been open to following the framework from the beginning they would have saved themselves a lot of stops and starts, resistance and headaches, and likely time and resources. So it's important for campuses to identify what steps they have already taken and then help consider next steps moving forward. However, it is important to keep the framework in the background to identify specific barriers and help teams return to issues they had ignored.

Wherever a campus starts, we believe you must somehow address all the elements at some point or time.

The entire process takes leadership. Leadership can take a variety of forms, from informal faculty leaders to formal institutional administrators. Regardless, though, leaders must understand change processes and management issues in order to help the team stay the course down the river of change. Leaders must also help their teams determine the best entry point and the questions in Table 1 are designed to help.

Table 1. Getting Started

Key Questions	*Yes or No?*	*If yes, then …*	*If no, then …*
Vision: Is there a campus vision and/or goal statement that is specific to __________________ related to student success? Do programs, departments and/or Colleges have articulated goals for _________________?		… use this as a lever to bring people together to discuss common goals and specific outcomes.	… this may be a good place to start. Present this as an opportunity to start a conversation about what is important regarding student learning and success.
Landscape Analysis: Does the campus regularly collect and analyze data regarding _________________, retention and graduation? Is there faculty or staff expertise with respect to		… tie the data to your vision if that hasn't already been done. Data can be an important lever for change and an opportunity	… this may be a good place to start, assuming there are appropriate resources and expertise for performing this type of analysis. If

________________?		for conversations with faculty and staff. Interview faculty, attend department meetings, leverage educational experts.	not, the campus may need to consider how it will obtain the expertise needed either through staffing or use of consultants.
Identify and analyze challenges: Has the campus identified student attributes, programmatic bottlenecks, policy, scheduling or other factors that impeded ________________?		… leverage this analysis for a focused discussion on specific areas where interventions might be fruitful.	… begin by collecting data and put together a team that can analyze it. This will be an important analysis to carry out and is a critical step needed before moving forward to the next step.
Choose strategies and interventions: Does the campus have any experience with implementation of evidence-based practices related to ________________ (e.g., course redesign, problem-based learning, summer bridge programs, supplemental instruction, learning communities, etc.)?		… bring the people who have this experience together to share their knowledge and assess results; tie results back to vision and landscape analysis to see how they fit together, identify where gaps exist and them create a plan for how to move forward that addresses concerns.	… conduct a review of the relevant literature (see section on strategies and interventions) as well as devoting resources to professional development opportunities for faculty and staff is warranted.

Questions to ask when considering this step:

1. Answer the questions provided in Table 1 (yes/no) column. Where do you think your team should start, based on your responses to the questions in Table 1? Why?

2. What challenges do you think might face? What opportunities might you have to leverage for starting at this point?

3. What will be your first three action steps, using the information in Table 1?

Action Step	When
1.	
2.	
3.	

Step 2. Establish your Framework baseline.
Before you get started, rate your campus' current status on the Framework elements below. Use this rubric to check in on your progress periodically. To determine your campus' status, identify the benchmark description that best fits your campus right now and tally your score. Fill out the worksheet questions provided in the separate worksheet document.

Table 2. Framework Rubric

	Benchmark			
Framework Element	**Developed (3 points)**	**Emerging (2 points)**	**Initial (1 point)**	**Score**
Vision	The campus has a well-defined statement that describes their collective vision for improving ________________________ (which may include overarching outcomes like quantitative reasoning). The vision includes clear goals for your efforts as well as specific outcomes and measures, and is linked to institutional mission and priorities.	Individual units may have statements that relate to ________________________; however, they are not coherent across relevant units or tied to institutional mission and priorities.	The campus has not developed a vision or goals for ________________________, although isolated courses may have these goals. There may also not be a campus-wide vision for student learning and success.	
Landscape and Capacity Analysis	The campus has a clear picture of how students are performing in classes and programs regarding ___________________________, as well as how this relates to student success (e.g., attainment of degrees); how, what and when they are learning; how they are moving into and through the institution; what roadblocks are	The campus has capacity for colleting and analyzing data but has not fully analyzed or disaggregated for ________________________, has not included faculty and administrators in discussion of data.	The campus has not yet collected or analyzed data on student learning or success; may not have the staff or other resources to collect and analyze data.	

	they facing; what programs or other factors facilitate their progression.			
Identify and Analyze Challenges	Specific challenges regarding ________________________ have been articulated and supported by evidence. Pointers to particular programmatic or institutional opportunities that might be leveraged have been recognized.	The campus may have a desire to implement one or more strategies but these are not connected to the evidence regarding student learning and success indicators; a few opportunities have been identified, although some may not be directly applicable.	There is a general lack of awareness among faculty and/or administrators regarding effective practices for promoting ______________________________; the campus has not identified any opportunities that might be leveraged.	
Strategy and Intervention Choice	Specific strategies or programmatic interventions have been identified that address the gaps or needs identified by the landscape analysis and are focused on the vision.	Programmatic strategies or interventions are not fully developed or do not address needs identified by landscape and capacity analysis.	Strategies have not been identified or developed.	
Determine Readiness	The campus has identified and obtained the faculty, staff, financial, physical and cultural resources to implement the identified strategies.	Some resources have been identified, although the campus may not have obtained all the needed resources.	No analysis or identification of resources has been completed.	
Implementation	The campus has carried out at least one pilot or small-scale implementation of their planned strategy and collected adequate assessment data to monitor effectiveness, make improvements and inform scale up.	Plans are not complete; scattered or isolated attempts at strategies may have been made by individuals or in single courses.	No plans to implement exist.	
Measuring	Key data will have been	Implementation has occurred;	No data has been collected or	

Impact	collected and analyzed to help campuses evaluate how well their plan worked, where it may have failed and how you might improve it for the next round of implementation and eventual scale up.	however, little or no data has been collected; dataset may be incomplete; if data has been collected it may not have been analyzed.	analyzed.	
Dissemination and Next Steps	Descriptions of project purpose, methods and results will be documented in various formats and venues, such as websites and newsletters, social media sites, campus presentations, community news articles, conference presentations, published papers. Plans are in place for modification, improvement and/or scale up.	Some descriptions of project goals and results may be available in project, department or college reports or campus website but are not widely available across campus or beyond. Planning for next steps may be incomplete, missing assessment data or other details, including those required for scale up.	Very little information about the project is available beyond those engaged in the process. No plan exists for applying lessons learned to future program implementation.	
TOTAL				

Questions to ask when considering this step:

1. What was your institution score on the rubric: a score of 8 indicates you are at the very beginning stages; a score of 24 indicates you are at a very advanced stage of work. Was your score expected, unexpected? Why?

2. What strengths, weaknesses and opportunities can you identify as a result of your rubric analysis?

Strengths	Weaknesses	Opportunities

Step 3. Team and Leadership Development

Team development is extremely important because the team is the engine creating the forward momentum of the project. Assembling the best team can take several months and we encourage projects to take the time to create high functioning teams. Once teams are created they also need time to get to know each other, create a common language and vision around the change, and build trust. Regular meetings or an in-depth annual retreat can facilitate team building. Before moving into the detailed work of data analysis and identifying interventions, team members need to trust each other, gain respect, understand each other's expertise, and develop relationships. Everyone must feel welcome and that they are in a safe environment for discussion of potentially controversial ideas or data and for free expression of opinions as well as experimentation with innovative interventions.

Having a team leader who can keep the team focused and on track is critical. If one or two senior leaders are willing to serve on the team or be able act as liaison this is helpful in gaining the type of leadership needed for institution wide change. Some teams find that they get better thinking by identifying unexpected people to put on the team—some one from technology services or other disciplines such as the humanities. It is also important for team leaders to continually reflect on the process to monitor team effectiveness as well as project progress. We provide questions that can be used by leaders to be mindful of team process and practice:

Leader Reflection Questions:

- *What aspects of this stage went well? Where did you encounter challenges? Were you able to overcome them? If so, how? If not, why not?*
- *What important team and/or institutional values were uncovered?*
- *What did you learn about what your campus does well and can further leverage?*
- *How well is your team functioning? How are you empowering and rewarding their work? Are there any issues – communication, collaboration, commitment, capacity? How are you addressing these challenges?*
- *What were your leadership challenges? What were your leadership successes?*
- *Overall, how well do you think the team executed this stage of the process? What might you do next time to improve?*

Questions to ask when considering this step:

1. Who do you think you need on the team? Think about the expertise you might need, expertise you have on campus and membership from across the institution.

Types of Expertise	**Name(s)**
Faculty	
Staff	
Student Affairs	
Office of Institutional Research	
Administration	
Students	
Other	
Other	

2. Who will lead the team? You will need faculty leaders and institutional champions.

    a. Faculty leaders:

    b. Institutional champions:

3. How will the team work and communicate?

Team Development Resources: For more guidance on working as a team, please see Bensimon and Neumann (1993) and also the Equity Scorecard Project's guides for campus teams (http://cue.usc.edu/our_tools/the_equity_scorecard.html).

Leadership Development Resources: Project Kaleidoscope offers a yearly summer leadership Institute (Elrod and Kezar, 2014). Close to 2,000 faculty have gone through the training and found it extremely important to assisting them in leading change efforts on campus as well as advancing in their careers and to roles as department chair, dean and provost. Many disciplinary societies offer leadership training at their annual meetings. Other faculty have developed their leadership skills by participating in regional and national STEM reform networks such as SENCER (Science Education for New Civic Engagement and Responsibilities; http://www.sencer.net), BioQUEST (http://bioquest.org), and POGIL (Process Oriented Guided Inquiry Learning; https://pogil.org). Each of these networks provides different opportunities for developing leadership skills, mostly through the lens of mounting projects related to undergraduate STEM reform. Campuses that are successful in reforming STEM typically send faculty to these various professional development opportunities to gain the skills required to lead processes like we describe in this guidebook. Faculty leaders, chair and deans may also realize greater success when they "lead up" by creating short talking points for higher level leaders so they can speak with authority about STEM education and/or campus projects. Additionally, senior leaders are needed to change reward structures, help with resources, and provide the infrastructure such as professional development or outcomes assessment to support long-term changes. Senior leaders are more likely to be supportive when they see the initiative is aligned with institutional goals. We found that campus teams were much more successful when they determined institutional priorities and aligns their STEM reform efforts with institutional goals.

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WASC Senior College and University Commission | EDUCATIONAL PROGRAMS

Breakout 7

Expectations for Student Performance at Graduation: What, Why, and How

H. Chen

M. Maloney

EXPECTATIONS FOR STUDENT PERFORMANCE AT GRADUATION: WHAT, WHY, AND HOW

Maureen A. Maloney, WSCUC
Helen L. Chen, Stanford University

October 3, 2014 Quantitative Reasoning and Assessment in Majors

Our Roadmap . . .

2

- Why the focus on standards of performance?
- What does WSCUC expect?
- How much autonomy do institutions have?
- How can we set and report on standards of performance?

"Gadfly, try not to tell too many people that you went to this school"

Is There a Quality Problem?

4

- *Academically Adrift,* (Arum and Roska, 2011)
- Wabash National Study of Liberal Arts Education
- National Survey of Student Engagement data
- Inside Higher Ed survey of provosts
- Employer surveys
- National Assessment of Adult Literacy
- Organisation for Economic Co-operation and Development (OECD) – Assessment of Higher Education Learning Outcomes

Is There an Accreditation Problem?

5

Does accreditation…

- focus on process or results? Inputs or outcomes?
- address proxies or actual learning?
- serve accountability or improvement?
- review rigorously – or is it a club of peers?
- protect institutions – or protect consumers?
- stimulate innovation – or stifle it?

WSCUC's Path to Learning Results

6

- 1996: *Invitation to Dialogue*
- 2001:
  - Significantly revised Standards
  - Three-part Accreditation Review: Proposal, Capacity and Preparatory Review, Educational Effectiveness review
- 2008: Stronger language on program review, program-level assessment
- 2013:
  - Lightly revised Standards,
  - Significantly Revised Institutional Review Process

WSCUC's Learning Curve ... and Yours

7

- FROM expecting programs to describe their ***process*** for assessing student learning . . .
- TO asking for the ***results*** of those assessments.

The Learning Curve . . .

8

- FROM WSCUC expecting programs to ***set standards*** for student learning . . .
- TO asking for ***evidence of student achievement*** of those standards

The Learning Curve . . .

9

- FROM evidence that the institution acts on findings and can show ***improvement***...
- TO also asking "Is this ***good enough***? How do we know? What means do we use to establish standards of performance or proficiency?"

Key Elements of WSCUC Senior Commission Actions

10

- Increased transparency (postings on web)
- Regular (annual?) financial reviews
- Assuring meaning, quality, and integrity of degrees (DQP optional)
- **Reporting students' performance at graduation in five core competencies in relation to a standard defined by the institution**
- Reporting on "student success" (R/G + learning)
- Reporting vision, plans for future viability

Standards of Performance at Graduation

11

- Core competencies (in Standard 2 since 2001):
  - Written communication
  - Oral communication
  - Quantitative reasoning
  - Critical thinking
  - Information literacy
- Program/major field outcomes
- Distinctive outcomes identified by institution
- For graduate programs: "key competencies"

Standards of Performance at Graduation *(continued)*

12

Institution's responsibility:

- define each competency or outcome
- Establish an institutional standard of performance at or near graduation: "appropriately ambitious"
- Assess, (dis)aggregate findings
- **Show extent to which students' performance meets the institution's standard of performance**
- If improvement is needed, create a plan, with criteria, timeline, metrics, for judging progress
- Report to WSCUC

Standards of Performance at Graduation
(continued)

13

- WSCUC's responsibility:
  to provide support, be a partner in the process
- WSCUC will accept . . .
  - Variations within and across institutions
  - Multiple methods and approaches
  - Gradual implementation
  - Innovation, experimentation

14

Some Definitions from Merriam-Webster

15

- ***Compare:*** to examine character or qualities especially in order to discover resemblances or differences
- ***Benchmark:*** a point of reference from which measurements may be made; *b*: something that serves as a standard by which others may be measured or judged

More Definitions . . .

16

- ***Criterion-referenced*:** testing or assessment in which student performance is judged in relation to **pre-established standards** and not in relation to the performance of other students.
- ***Norm-referenced*:** testing or assessment in which student performance is judged in relation to the **performance of a larger group of students,** not measured against a pre-established standard.

Learning and Performance Standards

17

- ***Absolute*** standards: the knowledge/skill level of prizewinners, champions, top experts
- ***Contextual*** standards: appropriate expectations for, e.g., a 10-year old, a college student, an experienced professional
- ***Developmental*** standards: the amount of growth, progress over time, e.g., 2 years of college, 3 years of graduate school
- (***Regional, national, international*** standards – emerging?)

How Do We Define a Standard of Performance?

18

Consider…

- Your baseline, e.g. current graduating students' achievement
- Previous class(es) of graduates (or rising juniors, transfers, others)
- Students' progress from entry to exit

Comparisons/Benchmarks

(continued)

19

Expectations

- □ given SAT scores, SES, other predictors
- □ Your faculty's ambitions for students
- □ Student scores at peer institutions:
  - > actual peers
  - > aspirational peers
- □ from the public, employers, policy makers

Key Elements of WSCUC's Approach to Standards of Performance:

20

1. Standards of performance are defined by the institution, not WSCUC;
2. Assessment methods are chosen by the institution, not WSCUC; and
3. Institutions are urged to contextualize results, data/evidence, relative to similar types of institutions and a larger universe.
4. Benchmarking is encouraged, but not required.

WSCUC’s Role: To validate that the institution has…

21

1. set its own standards of performance;
2. calibrated its level of performance and proficiency in some way, e.g., internally, against peers, employer expectations
3. generated data/evidence of learning results;
4. developed plans for improvement where needed

How to Set Standards of Performance?

22

1. Choose a focus, e.g., written communication
2. Create a work group: membership may be
   - ***Internal***: from across the institution
   - ***External***: e.g., from peer institutions, feeder/receiver schools, geographical neighbors, etc.
3. Choose a common method of assessment

How to Set Standards of Performance?

(continued)

23

4. Analyze assessment findings collaboratively
5. Set a shared contextual standard (calibration)
6. Assess again, *compare student results to the standard*
7. Identify and replicate the variables that lead to higher student performance
8. Build in external validation
9. (For a national comparison, use a commercially available test or survey)

Benefits of Setting Standards

24

- The institution/program has a context for judging “success,” how “good” it is, whether “good enough”
- Assessment findings, data become more meaningful
- “Best practice” institutions/programs offer models that work
- Standards sharpen the focus on improvement of learning, teaching, curriculum
- The institution/program knows where it stands in relation to others
- Assertions of quality are more informed, credible

Potential Pitfalls

25

1. Setting the standard too low
2. Assessing what is easy, instead of what is important
3. Overvaluing quantitative indicators
4. Overvaluing the qualitative: Everyone's so unique that nothing can be compared, no standards can be set.

Potential Pitfalls
(continued)

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5. Focusing "within the box," on current results; not looking beyond, to higher ambitions, "out of the box" innovation
6. Fear, which shuts down candor, collaboration, learning
7. A competitive approach, pitting collaborators against each other
8. Temptation to game the system: improve the appearance but not the reality

Closing Thoughts . . .

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- Standards of performance are a powerful tool.
- They are a means, not the end.
- They are the logical next step for assessment – and accreditation.
- Used thoughtfully, they can move our institutions and higher education into the 21st century

For more information

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WASC Senior College and University Commission | EDUCATIONAL PROGRAMS

RESOURCES

WASC Senior College and University Commission | EDUCATIONAL PROGRAMS

Association of American Colleges & Universities (AAC&U) VALUE Rubrics

CRITICAL THINKING VALUE RUBRIC

for more information, please contact value@aacu.org

The VALUE rubrics were developed by teams of faculty experts representing colleges and universities across the United States through a process that examined many existing campus rubrics and related documents for each learning outcome and incorporated additional feedback from faculty. The rubrics articulate fundamental criteria for each learning outcome, with performance descriptors demonstrating progressively more sophisticated levels of attainment. The rubrics are intended for institutional-level use in evaluating and discussing student learning, not for grading. The core expectations articulated in all 15 of the VALUE rubrics can and should be translated into the language of individual campuses, disciplines, and even courses. The utility of the VALUE rubrics is to position learning at all undergraduate levels within a basic framework of expectations such that evidence of learning can by shared nationally through a common dialog and understanding of student success.

Definition

Critical thinking is a habit of mind characterized by the comprehensive exploration of issues, ideas, artifacts, and events before accepting or formulating an opinion or conclusion.

Framing Language

This rubric is designed to be transdisciplinary, reflecting the recognition that success in all disciplines requires habits of inquiry and analysis that share common attributes. Further, research suggests that successful critical thinkers from all disciplines increasingly need to be able to apply those habits in various and changing situations encountered in all walks of life.

This rubric is designed for use with many different types of assignments and the suggestions here are not an exhaustive list of possibilities. Critical thinking can be demonstrated in assignments that require students to complete analyses of text, data, or issues. Assignments that cut across presentation mode might be especially useful in some fields. If insight into the process components of critical thinking (e.g., how information sources were evaluated regardless of whether they were included in the product) is important, assignments focused on student reflection might be especially illuminating.

Glossary

The definitions that follow were developed to clarify terms and concepts used in this rubric only.

- Ambiguity: Information that may be interpreted in more than one way.
- Assumptions: Ideas, conditions, or beliefs (often implicit or unstated) that are "taken for granted or accepted as true without proof." (quoted from www.dictionary.reference.com/browse/assumptions)
- Context: The historical, ethical. political, cultural, environmental, or circumstantial settings or conditions that influence and complicate the consideration of any issues, ideas, artifacts, and events.
- Literal meaning: Interpretation of information exactly as stated. For example, "she was green with envy" would be interpreted to mean that her skin was green.
- Metaphor: Information that is (intended to be) interpreted in a non-literal way. For example, "she was green with envy" is intended to convey an intensity of emotion, not a skin color.

CRITICAL THINKING VALUE RUBRIC

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Association of American Colleges and Universities

Definition

Critical thinking is a habit of mind characterized by the comprehensive exploration of issues, ideas, artifacts, and events before accepting or formulating an opinion or conclusion.

Evaluators are encouraged to assign a zero to any work sample or collection of work that does not meet benchmark (cell one) level performance.

	Capstone 4	Milestones 3	2	Benchmark 1
Explanation of issues	Issue/problem to be considered critically is stated clearly and described comprehensively, delivering all relevant information necessary for full understanding.	Issue/problem to be considered critically is stated, described, and clarified so that understanding is not seriously impeded by omissions.	Issue/problem to be considered critically is stated but description leaves some terms undefined, ambiguities unexplored, boundaries undetermined, and/or backgrounds unknown.	Issue/problem to be considered critically is stated without clarification or description.
Evidence *Selecting and using information to investigate a point of view or conclusion*	Information is taken from source(s) with enough interpretation/evaluation to develop a comprehensive analysis or synthesis. Viewpoints of experts are questioned thoroughly.	Information is taken from source(s) with enough interpretation/evaluation to develop a coherent analysis or synthesis. Viewpoints of experts are subject to questioning.	Information is taken from source(s) with some interpretation/evaluation, but not enough to develop a coherent analysis or synthesis. Viewpoints of experts are taken as mostly fact, with little questioning.	Information is taken from source(s) without any interpretation/evaluation. Viewpoints of experts are taken as fact, without question.
Influence of context and assumptions	Thoroughly (systematically and methodically) analyzes own and others' assumptions and carefully evaluates the relevance of contexts when presenting a position.	Identifies own and others' assumptions and several relevant contexts when presenting a position.	Questions some assumptions. Identifies several relevant contexts when presenting a position. May be more aware of others' assumptions than one's own (or vice versa).	Shows an emerging awareness of present assumptions (sometimes labels assertions as assumptions). Begins to identify some contexts when presenting a position.
Student's position (perspective, thesis/hypothesis)	Specific position (perspective, thesis/hypothesis) is imaginative, taking into account the complexities of an issue. Limits of position (perspective, thesis/hypothesis) are acknowledged. Others' points of view are synthesized within position (perspective, thesis/hypothesis).	Specific position (perspective, thesis/hypothesis) takes into account the complexities of an issue. Others' points of view are acknowledged within position (perspective, thesis/hypothesis).	Specific position (perspective, thesis/hypothesis) acknowledges different sides of an issue.	Specific position (perspective, thesis/hypothesis) is stated, but is simplistic and obvious.
Conclusions and related outcomes (implications and consequences)	Conclusions and related outcomes (consequences and implications) are logical and reflect student's informed evaluation and ability to place evidence and perspectives discussed in priority order.	Conclusion is logically tied to a range of information, including opposing viewpoints; related outcomes (consequences and implications) are identified clearly.	Conclusion is logically tied to information (because information is chosen to fit the desired conclusion); some related outcomes (consequences and implications) are identified clearly.	Conclusion is inconsistently tied to some of the information discussed; related outcomes (consequences and implications) are oversimplified.

Problem Solving VALUE Rubric

for more information, please contact value@aacu.org

Association of American Colleges and Universities

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Definition

Problem solving is the process of designing, evaluating and implementing a strategy to answer an open-ended question or achieve a desired goal.

Framing Language

Problem-solving covers a wide range of activities that may vary significantly across disciplines. Activities that encompass problem-solving by students may involve problems that range from well-defined to ambiguous in a simulated or laboratory context, or in real-world settings. This rubric distills the common elements of most problem-solving contexts and is designed to function across all disciplines. It is broad-based enough to allow for individual differences among learners, yet is concise and descriptive in its scope to determine how well students have maximized their respective abilities to practice thinking through problems in order to reach solutions.

This rubric is designed to measure the quality of a **process**, rather than the quality of an **end-product**. As a result, work samples or collections of work will need to include some evidence of the individual's thinking about a problem-solving task (e.g., reflections on the process from problem to proposed solution; steps in a problem-based learning assignment; record of think-aloud protocol while solving a problem). The final product of an assignment that required problem resolution is insufficient without insight into the student's problem-solving process. Because the focus is on institutional level assessment, scoring team projects, such as those developed in capstone courses, may be appropriate as well.

Glossary

The definitions that follow were developed to clarify terms and concepts used in this rubric only.

- Contextual Factors: Constraints (such as limits on cost), resources, attitudes (such as biases) and desired additional knowledge which affect how the problem can be best solved in the real world or simulated setting.
- Critique: Involves analysis and synthesis of a full range of perspectives.
- Feasible: Workable, in consideration of time-frame, functionality, available resources, necessary buy-in, and limits of the assignment or task.
- "Off the shelf" solution: A simplistic option that is familiar from everyday experience but not tailored to the problem at hand (e.g. holding a bake sale to "save" an underfunded public library).
- Solution: An appropriate response to a challenge or a problem.
- Strategy: A plan of action or an approach designed to arrive at a solution. (If the problem is a river that needs to be crossed, there could be a construction-oriented, cooperative (build a bridge with your community) approach and a personally oriented, physical (swim across alone) approach. An approach that partially applies would be a personal, physical approach for someone who doesn't know how to swim.
- Support: Specific rationale, evidence, etc. for solution or selection of solution.

Problem Solving VALUE Rubric

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Association of American Colleges and Universities

Definition

Problem solving is the process of designing, evaluating, and implementing a strategy to answer an open-ended question or achieve a desired goal.

Evaluators are encouraged to assign a zero to any work sample or collection of work that does not meet benchmark (cell one) level performance.

	Capstone 4	Milestones 3	 2	Benchmark 1
Define Problem	Demonstrates the ability to construct a clear and insightful problem statement with evidence of all relevant contextual factors.	Demonstrates the ability to construct a problem statement with evidence of most relevant contextual factors, and problem statement is adequately detailed.	Begins to demonstrate the ability to construct a problem statement with evidence of most relevant contextual factors, but problem statement is superficial.	Demonstrates a limited ability in identifying a problem statement or related contextual factors.
Identify Strategies	Identifies multiple approaches for solving the problem that apply within a specific context.	Identifies multiple approaches for solving the problem, only some of which apply within a specific context.	Identifies only a single approach for solving the problem that does apply within a specific context.	Identifies one or more approaches for solving the problem that do not apply within a specific context.
Propose Solutions/Hypotheses	Proposes one or more solutions/hypotheses that indicates a deep comprehension of the problem. Solution/hypotheses are sensitive to contextual factors as well as all of the following: ethical, logical, and cultural dimensions of the problem.	Proposes one or more solutions/hypotheses that indicates comprehension of the problem. Solutions/hypotheses are sensitive to contextual factors as well as the one of the following: ethical, logical, or cultural dimensions of the problem.	Proposes one solution/hypothesis that is "off the shelf" rather than individually designed to address the specific contextual factors of the problem.	Proposes a solution/hypothesis that is difficult to evaluate because it is vague or only indirectly addresses the problem statement.
Evaluate Potential Solutions	Evaluation of solutions is deep and elegant (for example, contains thorough and insightful explanation) and includes, deeply and thoroughly, all of the following: considers history of problem, reviews logic/reasoning, examines feasibility of solution, and weighs impacts of solution.	Evaluation of solutions is adequate (for example, contains thorough explanation) and includes the following: considers history of problem, reviews logic/reasoning, examines feasibility of solution, and weighs impacts of solution.	Evaluation of solutions is brief (for example, explanation lacks depth) and includes the following: considers history of problem, reviews logic/reasoning, examines feasibility of solution, and weighs impacts of solution.	Evaluation of solutions is superficial (for example, contains cursory, surface level explanation) and includes the following: considers history of problem, reviews logic/reasoning, examines feasibility of solution, and weighs impacts of solution.
Implement Solution	Implements the solution in a manner that addresses thoroughly and deeply multiple contextual factors of the problem.	Implements the solution in a manner that addresses multiple contextual factors of the problem in a surface manner.	Implements the solution in a manner that addresses the problem statement but ignores relevant contextual factors.	Implements the solution in a manner that does not directly address the problem statement.
Evaluate Outcomes	Reviews results relative to the problem defined with thorough, specific considerations of need for further work.	Reviews results relative to the problem defined with some consideration of need for further work.	Reviews results in terms of the problem defined with little, if any, consideration of need for further work.	Reviews results superficially in terms of the problem defined with no consideration of need for further work

Inquiry and Analysis VALUE Rubric

for more information, please contact value@aacu.org

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Definition

Inquiry is a systematic process of exploring issues, objects or works through the collection and analysis of evidence that results in informed conclusions or judgments. Analysis is the process of breaking complex topics or issues into parts to gain a better understanding of them.

Framing Language

This rubric is designed for use in a wide variety of disciplines. Since the terminology and process of inquiry are discipline-specific, an effort has been made to use broad language which reflects multiple approaches and assignments while addressing the fundamental elements of sound inquiry and analysis (including topic selection, existing, knowledge, design, analysis, etc.) The rubric language assumes that the inquiry and analysis process carried out by the student is appropriate for the discipline required. For example, if analysis using statistical methods is appropriate for the discipline then a student would be expected to use an appropriate statistical methodology for that analysis. If a student does not use a discipline-appropriate process for any criterion, that work should receive a performance rating of "1" or "0" for that criterion.

In addition, this rubric addresses the **products** of analysis and inquiry, not the **processes** themselves. The complexity of inquiry and analysis tasks is determined in part by how much information or guidance is provided to a student and how much the student constructs. The more the student constructs, the more complex the inquiry process. For this reason, while the rubric can be used if the assignments or purposes for work are unknown, it will work most effectively when those are known. Finally, faculty are encouraged to adapt the essence and language of each rubric criterion to the disciplinary or interdisciplinary context to which it is applied.

Glossary

The definitions that follow were developed to clarify terms and concepts used in this rubric only.

- Conclusions: A synthesis of key findings drawn from research/evidence.
- Limitations: Critique of the process or evidence.
- Implications: How inquiry results apply to a larger context or the real world.

INQUIRY AND ANALYSIS VALUE RUBRIC

for more information, please contact value@aacu.org

Association of American Colleges and Universities

Definition

Inquiry is a systematic process of exploring issues/objects/works through the collection and analysis of evidence that result in informed conclusions/judgments. Analysis is the process of breaking complex topics or issues into parts to gain a better understanding of them.

Evaluators are encouraged to assign a zero to any work sample or collection of work that does not meet benchmark (cell one) level performance.

	Capstone 4	**Milestones** 3	 2	**Benchmark** 1
Topic selection	Identifies a creative, focused, and manageable topic that addresses potentially significant yet previously less-explored aspects of the topic.	Identifies a focused and manageable/doable topic that appropriately addresses relevant aspects of the topic.	Identifies a topic that while manageable/doable, is too narrowly focused and leaves out relevant aspects of the topic.	Identifies a topic that is far too general and wide-ranging as to be manageable and doable.
Existing Knowledge, Research, and/or Views	Synthesizes in-depth information from relevant sources representing various points of view/approaches.	Presents in-depth information from relevant sources representing various points of view/approaches.	Presents information from relevant sources representing limited points of view/approaches.	Presents information from irrelevant sources representing limited points of view/approaches.
Design Process	All elements of the methodology or theoretical framework are skillfully developed. Appropriate methodology or theoretical frameworks may be synthesized from across disciplines or from relevant subdisciplines.	Critical elements of the methodology or theoretical framework are appropriately developed, however, more subtle elements are ignored or unaccounted for.	Critical elements of the methodology or theoretical framework are missing, incorrectly developed, or unfocused.	Inquiry design demonstrates a misunderstanding of the methodology or theoretical framework.
Analysis	Organizes and synthesizes evidence to reveal insightful patterns, differences, or similarities related to focus.	Organizes evidence to reveal important patterns, differences, or similarities related to focus.	Organizes evidence, but the organization is not effective in revealing important patterns, differences, or similarities.	Lists evidence, but it is not organized and/or is unrelated to focus.
Conclusions	States a conclusion that is a logical extrapolation from the inquiry findings.	States a conclusion focused solely on the inquiry findings. The conclusion arises specifically from and responds specifically to the inquiry findings.	States a general conclusion that, because it is so general, also applies beyond the scope of the inquiry findings.	States an ambiguous, illogical, or unsupportable conclusion from inquiry findings.
Limitations and Implications	Insightfully discusses in detail relevant and supported limitations and implications.	Discusses relevant and supported limitations and implications.	Presents relevant and supported limitations and implications.	Presents limitations and implications, but they are possibly irrelevant and unsupported.

QUANTITATIVE LITERACY VALUE RUBRIC

for more information, please contact value@aacu.org

Association of American Colleges and Universities

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Definition

Quantitative Literacy (QL) – also known as Numeracy or Quantitative Reasoning (QR) – is a "habit of mind," competency, and comfort in working with numerical data. Individuals with strong QL skills possess the ability to reason and solve quantitative problems from a wide array of authentic contexts and everyday life situations. They understand and can create sophisticated arguments supported by quantitative evidence and they can clearly communicate those arguments in a variety of formats (using words, tables, graphs, mathematical equations, etc., as appropriate).

Quantitative Literacy Across the Disciplines

Current trends in general education reform demonstrate that faculty are recognizing the steadily growing importance of Quantitative Literacy (QL) in an increasingly quantitative and data-dense world. AAC&U's recent survey showed that concerns about QL skills are shared by employers, who recognize that many of today's students will need a wide range of high level quantitative skills to complete their work responsibilities. Virtually all of today's students, regardless of career choice, will need basic QL skills such as the ability to draw information from charts, graphs, and geometric figures, and the ability to accurately complete straightforward estimations and calculations.

Preliminary efforts to find student work products which demonstrate QL skills proved a challenge in this rubric creation process. It's possible to find pages of mathematical problems, but what those problem sets don't demonstrate is whether the student was able to think about and understand the meaning of her work. It's possible to find research papers that include quantitative information, but those papers often don't provide evidence that allows the evaluator to see how much of the thinking was done by the original source (often carefully cited in the paper) and how much was done by the student herself, or whether conclusions drawn from analysis of the source material are even accurate.

Given widespread agreement about the importance of QL, it becomes incumbent on faculty to develop new kinds of assignments which give students substantive, contextualized experience in using such skills as analyzing quantitative information, representing quantitative information in appropriate forms, completing calculations to answer meaningful questions, making judgments based on quantitative data and communicating the results of that work for various purposes and audiences. As students gain experience with those skills, faculty must develop assignments that require students to create work products which reveal their thought processes and demonstrate the range of their QL skills.

This rubric provides for faculty a definition for QL and a rubric describing four levels of QL achievement which might be observed in work products within work samples or collections of work. Members of AAC&U's rubric development team for QL hope that these materials will aid in the assessment of QL – but, equally important, we hope that they will help institutions and individuals in the effort to more thoroughly embed QL across the curriculum of colleges and universities.

Framing Language

This rubric has been designed for the evaluation of work that addresses quantitative literacy (QL) in a substantive way. QL is not just computation, not just the citing of someone else's data. QL is a habit of mind, a way of thinking about the world that relies on data and on the mathematical analysis of data to make connections and draw conclusions. Teaching QL requires us to design assignments that address authentic, data-based problems. Such assignments may call for the traditional written paper, but we can imagine other alternatives: a video of a PowerPoint presentation, perhaps, or a well designed series of web pages. In any case, a successful demonstration of QL will place the mathematical work in the context of a full and robust discussion of the underlying issues addressed by the assignment.

Finally, QL skills can be applied to a wide array of problems of varying difficulty, confounding the use of this rubric. For example, the same student might demonstrate high levels of QL achievement when working on a simplistic problem and low levels of QL achievement when working on a very complex problem. Thus, to accurately assess a students QL achievement it may be necessary to measure QL achievement within the context of problem complexity, much as is done in diving competitions where two scores are given, one for the difficulty of the dive, and the other for the skill in accomplishing the dive. In this context, that would mean giving one score for the complexity of the problem and another score for the QL achievement in solving the problem.

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Evaluators are encouraged to assign a zero to any work sample or collection of work that does not meet benchmark (cell one) level performance.

	Capstone 4	**Milestones** 3	2	1
Interpretation *Ability to explain information presented in mathematical forms (e.g., equations, graphs, diagrams, tables, words)*	Provides accurate explanations of information presented in mathematical forms. Makes appropriate inferences based on that information. *For example, accurately explains the trend data shown in a graph and makes reasonable predictions regarding what the data suggest about future events.*	Provides accurate explanations of information presented in mathematical forms. *For instance, accurately explains the trend data shown in a graph.*	Provides somewhat accurate explanations of information presented in mathematical forms, but occasionally makes minor errors related to computations or units. *For instance, accurately explains trend data shown in a graph, but may miscalculate the slope of the trend line.*	Attempts to explain information presented in mathematical forms, but draws incorrect conclusions about what the information means. *For example, attempts to explain the trend data shown in a graph, but will frequently misinterpret the nature of that trend, perhaps by confusing positive and negative trends.*
Representation *Ability to convert relevant information into various mathematical forms (e.g., equations, graphs, diagrams, tables, words)*	Skillfully converts relevant information into an insightful mathematical portrayal in a way that contributes to a further or deeper understanding.	Competently converts relevant information into an appropriate and desired mathematical portrayal.	Completes conversion of information but resulting mathematical portrayal is only partially appropriate or accurate.	Completes conversion of information but resulting mathematical portrayal is inappropriate or inaccurate.
Calculation	Calculations attempted are essentially all successful and sufficiently comprehensive to solve the problem. Calculations are also presented elegantly (clearly, concisely, etc.)	Calculations attempted are essentially all successful and sufficiently comprehensive to solve the problem.	Calculations attempted are either unsuccessful or represent only a portion of the calculations required to comprehensively solve the problem.	Calculations are attempted but are both unsuccessful and are not comprehensive.
Application / Analysis *Ability to make judgments and draw appropriate conclusions based on the quantitative analysis of data, while recognizing the limits of this analysis*	Uses the quantitative analysis of data as the basis for deep and thoughtful judgments, drawing insightful, carefully qualified conclusions from this work.	Uses the quantitative analysis of data as the basis for competent judgments, drawing reasonable and appropriately qualified conclusions from this work.	Uses the quantitative analysis of data as the basis for workmanlike (without inspiration or nuance, ordinary) judgments, drawing plausible conclusions from this work.	Uses the quantitative analysis of data as the basis for tentative, basic judgments, although is hesitant or uncertain about drawing conclusions from this work.
Assumptions *Ability to make and evaluate important assumptions in estimation, modeling, and data analysis*	Explicitly describes assumptions and provides compelling rationale for why each assumption is appropriate. Shows awareness that confidence in final conclusions is limited by the accuracy of the assumptions.	Explicitly describes assumptions and provides compelling rationale for why assumptions are appropriate.	Explicitly describes assumptions.	Attempts to describe assumptions.
Communication *Expressing quantitative evidence in support of the argument or purpose of the work (in terms of what evidence is used and how it is formatted, presented, and contextualized)*	Uses quantitative information in connection with the argument or purpose of the work, presents it in an effective format, and explicates it with consistently high quality.	Uses quantitative information in connection with the argument or purpose of the work, though data may be presented in a less than completely effective format or some parts of the explication may be uneven.	Uses quantitative information, but does not effectively connect it to the argument or purpose of the work.	Presents an argument for which quantitative evidence is pertinent, but does not provide adequate explicit numerical support. (May use quasi-quantitative words such as "many," "few," "increasing," "small," and the like in place of actual quantities.)

WASC Senior College and University Commission | EDUCATIONAL PROGRAMS

WASC RUBRICS

PROGRAM LEARNING OUTCOMES

Rubric for Assessing the Quality of Academic Program Learning Outcomes

Criterion	Initial	Emerging	Developed	Highly Developed
Comprehensive List	The list of outcomes is problematic: e.g., very incomplete, overly detailed, inappropriate, disorganized. It may include only discipline-specific learning, ignoring relevant institution-wide learning. The list may confuse learning processes (e.g., doing an internship) with learning outcomes (e.g., application of theory to real-world problems).	The list includes reasonable outcomes but does not specify expectations for the program as a whole. Relevant institution-wide learning outcomes and/or national disciplinary standards may be ignored. Distinctions between expectations for undergraduate and graduate programs may be unclear.	The list is a well-organized set of reasonable outcomes that focus on the key knowledge, skills, and values students learn in the program. It includes relevant institution-wide outcomes (e.g., communication or critical thinking skills). Outcomes are appropriate for the level (undergraduate vs. graduate); national disciplinary standards have been considered.	The list is reasonable, appropriate, and comprehensive, with clear distinctions between undergraduate and graduate expectations, if applicable. National disciplinary standards have been considered. Faculty have agreed on explicit criteria for assessing students' level of mastery of each outcome.
Assessable Outcomes	Outcome statements do not identify what students can do to demonstrate learning. Statements such as "Students understand scientific method" do not specify how understanding can be demonstrated and assessed.	Most of the outcomes indicate how students can demonstrate their learning.	Each outcome describes how students can demonstrate learning, e.g., "Graduates can write reports in APA style" or "Graduates can make original contributions to biological knowledge."	Outcomes describe how students can demonstrate their learning. Faculty have agreed on explicit criteria statements, such as rubrics, and have identified examples of student performance at varying levels for each outcome.
Alignment	There is no clear relationship between the outcomes and the curriculum that students experience.	Students appear to be given reasonable opportunities to develop the outcomes in the required curriculum.	The curriculum is designed to provide opportunities for students to learn and to develop increasing sophistication with respect to each outcome. This design may be summarized in a curriculum map.	Pedagogy, grading, the curriculum, relevant student support services, and co-curriculum are explicitly and intentionally aligned with each outcome. Curriculum map indicates increasing levels of proficiency.
Assessment Planning	There is no formal plan for assessing each outcome.	The program relies on short-term planning, such as selecting which outcome(s) to assess in the current year.	The program has a reasonable, multi-year assessment plan that identifies when each outcome will be assessed. The plan may explicitly include analysis and implementation of improvements.	The program has a fully-articulated, sustainable, multi-year assessment plan that describes when and how each outcome will be assessed and how improvements based on findings will be implemented. The plan is routinely examined and revised, as needed.
The Student Experience	Students know little or nothing about the overall outcomes of the program. Communication of outcomes to students, e.g. in syllabi or catalog, is spotty or nonexistent.	Students have some knowledge of program outcomes. Communication is occasional and informal, left to individual faculty or advisors.	Students have a good grasp of program outcomes. They may use them to guide their own learning. Outcomes are included in most syllabi and are readily available in the catalog, on the web page, and elsewhere.	Students are well-acquainted with program outcomes and may participate in creation and use of rubrics. They are skilled at self-assessing in relation to the outcomes and levels of performance. Program policy calls for inclusion of outcomes in all course syllabi, and they are readily available in other program documents.

How Visiting Team Members Can Use the Learning Outcomes Rubric

Conclusions should be based on a review of learning outcomes and assessment plans. Although you can make some preliminary judgments about alignment based on examining the curriculum or a curriculum map, you will have to interview key departmental representatives, such as department chairs, faculty, and students, to fully evaluate the alignment of the learning environment with the outcomes.

The rubric has five major dimensions:

1. **Comprehensive List**. The set of program learning outcomes should be a short but comprehensive list of the most important knowledge, skills, and values students learn in the program, including relevant institution-wide outcomes such as those dealing with communication skills, critical thinking, or information literacy. Faculty generally should expect higher levels of sophistication for graduate programs than for undergraduate programs, and they should consider national disciplinary standards when developing and refining their outcomes, if available. There is no strict rule concerning the optimum number of outcomes, but quality is more important than quantity. Faculty should not confuse learning processes (e.g., completing an internship) with learning outcomes (what is learned in the internship, such as application of theory to real-world practice). Questions. Is the list reasonable, appropriate and well-organized? Are relevant institution-wide outcomes, such as information literacy, included? Are distinctions between undergraduate and graduate outcomes clear? Have national disciplinary standards been considered when developing and refining the outcomes? Are explicit criteria – as defined in a rubric, for example – available for each outcome?
2. **Assessable Outcomes**. Outcome statements should specify what students can do to demonstrate their learning. For example, an outcome might state that “Graduates of our program can collaborate effectively to reach a common goal” or that “Graduates of our program can design research studies to test theories and examine issues relevant to our discipline.” These outcomes are assessable because faculty can observe the quality of collaboration in teams, and they can review the quality of student-created research designs. Criteria for assessing student products or behaviors usually are specified in rubrics, and the department should develop examples of varying levels of student performance (i.e., work that does not meet expectations, meets expectations, and exceeds expectations) to illustrate levels. Questions. Do the outcomes clarify how students can demonstrate learning? Have the faculty agreed on explicit criteria, such as rubrics, for assessing each outcome? Do they have examples of work representing different levels of mastery for each outcome?
3. **Alignment**. Students cannot be held responsible for mastering learning outcomes unless they have participated in a program that systematically supports their development. The curriculum should be explicitly designed to provide opportunities for students to develop increasing sophistication with respect to each outcome. This design often is summarized in a curriculum map—a matrix that shows the relationship between courses in the required curriculum and the program’s learning outcomes. Pedagogy and grading should be aligned with outcomes to foster and encourage student growth and to provide students helpful feedback on their development. Since learning occurs within and outside the classroom, relevant student services (e.g., advising and tutoring centers) and co-curriculum (e.g., student clubs and campus events) should be designed to support the outcomes. Questions. Is the curriculum explicitly aligned with the program outcomes? Do faculty select effective pedagogy and use grading to promote learning? Are student support services and the co-curriculum explicitly aligned to promote student development of the learning outcomes?
4. **Assessment Planning**. Faculty should develop explicit plans for assessing each outcome. Programs need not assess every outcome every year, but faculty should have a plan to cycle through the outcomes over a reasonable period of time, such as the period for program review cycles. Questions. Does the plan clarify when, how, and how often each outcome will be assessed? Will all outcomes be assessed over a reasonable period of time? Is the plan sustainable, in terms of human, fiscal, and other resources? Are assessment plans revised, as needed?
5. **The Student Experience**. At a minimum, students should be aware of the learning outcomes of the program(s) in which they are enrolled; ideally, they should be included as partners in defining and applying the outcomes and the criteria for levels of sophistication. Thus it is essential to communicate learning outcomes to students consistently and meaningfully. Questions: Are the outcomes communicated to students? Do students understand what the outcomes mean and how they can further their own learning? Do students use the outcomes and criteria to self-assess? Do they participate in reviews of outcomes, criteria, curriculum design, or related activities?

PORTFOLIOS

Rubric for Assessing the Use of Portfolios for Assessing Program Learning Outcomes

Criterion	Initial	Emerging	Developed	Highly Developed
Clarification of Students' Task	Instructions to students for portfolio development provide insufficient detail for them to know what faculty expect. Instructions may not identify outcomes to be addressed in the portfolio.	Students receive some written instructions for their portfolios, but they still have problems determining what is required of them and/or why they are compiling a portfolio.	Students receive written instructions that describe faculty expectations in detail and include the purpose of the portfolio, types of evidence to include, role of the reflective essay (if required), and format of the finished product.	Students in the program understand the portfolio requirement and the rationale for it, and they view the portfolio as helping them develop self-assessment skills. Faculty may monitor the developing portfolio to provide formative feedback and/or advise individual students.
Valid Results	It is not clear that valid evidence for each relevant outcome is collected <u>and/or</u> individual reviewers use idiosyncratic criteria to assess student work.	Appropriate evidence is collected for each outcome, and faculty have discussed relevant criteria for assessing each outcome.	Appropriate evidence is collected for each outcome; faculty use explicit criteria, such as agreed-upon rubrics, to assess student attainment of each outcome. Rubrics are usually shared with students.	Assessment criteria, e.g., in the form of rubrics, have been pilot-tested and refined over time; they are shared with students, and student may have helped develop them. Feedback from external reviewers has led to refinements in the assessment process. The department also uses external benchmarking data.
Reliable Results	Those who review student work are not calibrated to apply assessment criteria in the same way, and there are no checks for inter-rater reliability.	Reviewers are calibrated to apply assessment criteria in the same way <u>or</u> faculty routinely check for inter-rater reliability.	Reviewers are calibrated to apply assessment criteria in the same way, and faculty routinely check for inter-rater reliability.	Reviewers are calibrated; faculty routinely find that assessment data have high inter-rater reliability.
Results Are Used	Results for each outcome are collected, but they are not discussed among the faculty.	Results for each outcome are collected and discussed by the faculty, but results have not been used to improve the program.	Results for each outcome are collected, discussed by faculty, and used to improve the program.	Faculty routinely discuss results, plan needed changes, secure necessary resources, and implement changes. They may collaborate with others, such as librarians or Student Affairs professionals, to improve student learning. Students may also participate in discussions and/or receive feedback, either individual or in the aggregate. Follow-up studies confirm that changes have improved learning.
If e-Portfolios Are Used	There is no technical support for students or faculty to learn the software or to deal with problems.	There is informal or minimal formal support for students and faculty.	Formal technical support is readily available and proactively assists in learning the software and solving problems.	Support is readily available, proactive, and effective. Tech support personnel may also participate in refining the overall portfolio process.

<u>How Visiting Team Members Can Use the Portfolio Rubric</u>

Portfolios can serve many purposes besides assessment; in fact, these other purposes are actually much more common. Portfolios may be compiled so students can share their work with family and friends. They may be designed to build students' confidence by showing development over time or by displaying best work. They may be used for advising and career counseling, or so students can show their work during a job interview. The first thing a team needs to do is determine that the portfolios are used for *assessment*, and not for another purpose.

Conclusions about the quality of the assessment process should be based on discussion with relevant department members (e.g., chair, assessment coordinator, faculty, students) and a review of the program's written portfolio assignment. Two common types of portfolios are:

- Showcase portfolios—collections of each student's best work
- Developmental portfolios—collections of work from early, middle, and late stages in the student's academic career that demonstrate growth Faculty generally require students to include a reflective essay that describes how the evidence in the portfolio demonstrates their achievement of program learning outcomes. Sometimes faculty monitor developing portfolios to provide formative feedback and/or advising to students, and sometimes they collect portfolios only as students near graduation. Portfolio assignments should clarify the purpose of the portfolio, what kinds of evidence should be included, and the format (e.g., paper vs. e-portfolios); and students should view the portfolio as contributing to their personal development.

***The rubric has five major dimensions and a fifth dimension limited to e-portfolios*:**

1. **Clarification of Students' Task**. Most students have never created a portfolio, and they need explicit guidance. <u>Questions</u>. Does the portfolio assignment provide sufficient detail so students understand the purpose, the types of evidence to include, the learning outcomes to address, the role of the reflective essay (if any), and the required format? Do students view the portfolio as contributing to their ability to self-assess? Do faculty use the developing portfolios to assist individual students?
2. **Valid Results**. Sometimes portfolios lack valid evidence for assessing particular outcomes. For example, portfolios may not allow faculty to assess how well students can deliver oral presentations. Judgments about that evidence need to be based on well-established, agreed-upon criteria that specify (usually in rubrics) how to identify work that meets or exceeds expectations. <u>Questions</u>: Do the portfolios systematically include valid evidence for each targeted outcome? Are faculty using well-established, agreed-upon criteria, such as rubrics, to assess the evidence for each outcome? Have faculty pilot tested and refined their process? Are criteria shared with students? Are they collaborating with colleagues at other institutions to secure benchmarking (comparison) data?
3. **Reliable Results**. Well-qualified judges should reach the same conclusions about a student's achievement of a learning outcome, demonstrating inter-rater reliability. If two judges independently assess a set of materials, their ratings can be correlated. Sometimes a discrepancy index is used. How often do the two raters give identical ratings, ratings one point apart, ratings two points apart, etc.? Data are reliable if the correlation is high and/or if discrepancies are small. Raters generally are calibrated ("normed") to increase reliability. Calibration usually involves a training session in which raters apply rubrics to pre-selected examples of student work that vary in quality, then reach consensus about the rating each example should receive. The purpose is to ensure that all raters apply the criteria in the same way so that each student's product would receive the same score, regardless of rater. <u>Questions</u>: Are reviewers calibrated? Are checks for inter-rater reliability made? Is there evidence of high inter-rater reliability?
4. **Results Are Used**. Assessment is a process designed to monitor and improve learning, so assessment findings should have an impact. Faculty should reflect on results for each outcome and decide if they are acceptable or disappointing. If results do not meet their standards, faculty should determine what changes should be made, e.g., in pedagogy, curriculum, student support, or faculty support. <u>Questions</u>: Do faculty collect assessment results, discuss them, and reach conclusions about student achievement? Do they develop explicit plans to improve student learning? Do they implement those plans? Do they have a history of securing necessary resources to support this implementation? Do they collaborate with other campus professionals to improve student learning? Do follow-up studies confirm that changes have improved learning?
5. **If e-Portfolios Are Used.** Faculty and students alike require support, especially when a new software program is introduced. Lack of support can lead to frustration and failure of the process. Support personnel may also have useful insights into how the portfolio assessment process can be refined. <u>Questions</u>: What is the quality and extent of technical support? Of inclusion in review and refinement of the portfolio process? What is the overall level of faculty and student satisfaction with the technology and support services?

CAPSTONES

Rubric for Assessing the Use of Capstone Experiences for Assessing Program Learning Outcomes

Criterion	Initial	Emerging	Developed	Highly Developed
Relevant Outcomes and Lines of Evidence Identified	It is not clear which program outcomes will be assessed in the capstone course.	The relevant outcomes are identified, e.g., ability to integrate knowledge to solve complex problems; however, concrete plans for collecting evidence for each outcome have not been developed.	Relevant outcomes are identified. Concrete plans for collecting evidence for each outcome are agreed upon and used routinely by faculty who staff the capstone course.	Relevant evidence is collected; faculty have agreed on explicit criteria statements, e.g., rubrics, and have identified examples of student performance at varying levels of mastery for each relevant outcome.
Valid Results	It is not clear that potentially valid evidence for each relevant outcome is collected <u>and/or</u> individual faculty use idiosyncratic criteria to assess student work or performances.	Faculty have reached general agreement on the types of evidence to be collected for each outcome; they have discussed relevant criteria for assessing each outcome but these are not yet fully defined.	Faculty have agreed on concrete plans for collecting relevant evidence for each outcome. Explicit criteria, e.g., rubrics, have been developed to assess the level of student attainment of each outcome.	Assessment criteria, such as rubrics, have been pilot-tested and refined over time; they usually are shared with students. Feedback from external reviewers has led to refinements in the assessment process, and the department uses external benchmarking data.
Reliable Results	Those who review student work are not calibrated to apply assessment criteria in the same way; there are no checks for inter-rater reliability.	Reviewers are calibrated to apply assessment criteria in the same way <u>or</u> faculty routinely check for inter-rater reliability.	Reviewers are calibrated to apply assessment criteria in the same way, <u>and</u> faculty routinely check for inter-rater reliability.	Reviewers are calibrated, and faculty routinely find assessment data have high inter-rater reliability.
Results Are Used	Results for each outcome may or may not be are collected. They are not discussed among faculty.	Results for each outcome are collected and may be discussed by the faculty, but results have not been used to improve the program.	Results for each outcome are collected, discussed by faculty, analyzed, and used to improve the program.	Faculty routinely discuss results, plan needed changes, secure necessary resources, and implement changes. They may collaborate with others, such as librarians or Student Affairs professionals, to improve results. Follow-up studies confirm that changes have improved learning.
The Student Experience	Students know little or nothing about the purpose of the capstone or outcomes to be assessed. It is just another course or requirement.	Students have some knowledge of the purpose and outcomes of the capstone. Communication is occasional, informal, left to individual faculty or advisors.	Students have a good grasp of purpose and outcomes of the capstone and embrace it as a learning opportunity. Information is readily avail-able in advising guides, etc.	Students are well-acquainted with purpose and outcomes of the capstone and embrace it. They may participate in refining the experience, outcomes, and rubrics. Information is readily available.

<u>How Visiting Team Members Can Use the Capstone Rubric</u>

Conclusions should be based on discussion with relevant department members (e.g., chair, assessment coordinator, faculty). A variety of capstone experiences can be used to collect assessment data, such as:

- courses, such as senior seminars, in which advanced students are required to consider the discipline broadly and integrate what they have learned in the curriculum
- specialized, advanced courses
- advanced-level projects conducted under the guidance of a faculty member or committee, such as research projects, theses, or dissertations
- advanced-level internships or practica, e.g., at the end of an MBA program

Assessment data for a variety of outcomes can be collected in such courses, particularly outcomes related to integrating and applying the discipline, information literacy, critical thinking, and research and communication skills.

***The rubric has five major dimensions*:**

1. **Relevant Outcomes and Evidence Identified**. It is likely that not all program learning outcomes can be assessed within a single capstone course or experience. <u>Questions</u>: Have faculty explicitly determined which program outcomes will be assessed in the capstone? Have they agreed on concrete plans for collecting evidence relevant to each targeted outcome? Have they agreed on explicit criteria, such as rubrics, for assessing the evidence? Have they identified examples of student performance for each outcome at varying performance levels (e.g., below expectations, meeting, exceeding expectations for graduation)?
2. **Valid Results**. A valid assessment of a particular outcome leads to accurate conclusions concerning students' achievement of that outcome. Sometimes faculty collect evidence that does not have the potential to provide valid conclusions. For example, a multiple-choice test will not provide evidence of students' ability to deliver effective oral presentations. Assessment requires the collection of valid evidence and judgments about that evidence that are based on well-established, agreed-upon criteria that specify how to identify low, medium, or high-quality work. <u>Questions</u>: Are faculty collecting valid evidence for each targeted outcome? Are they using well-established, agreed-upon criteria, such as rubrics, for assessing the evidence for each outcome? Have faculty pilot tested and refined their process based on experience and feedback from external reviewers? Are they sharing the criteria with their students? Are they using benchmarking (comparison) data?
3. **Reliable Results**. Well-qualified judges should reach the same conclusions about individual student's achievement of a learning outcome, demonstrating inter-rater reliability. If two judges independently assess a set of materials, their ratings can be correlated. Sometimes a discrepancy index is used. How often do the two raters give identical ratings, ratings one point apart, ratings two points apart, etc.? Data are reliable if the correlation is high and/or if the discrepancies are small. Raters generally are calibrated ("normed") to increase reliability. Calibration usually involves a training session in which raters apply rubrics to pre-selected examples of student work that vary in quality, then reach consensus about the rating each example should receive. The purpose is to ensure that all raters apply the criteria in the same way so that each student's product receives the same score, regardless of rater. <u>Questions</u>: Are reviewers calibrated? Are checks for inter-rater reliability made? Is there evidence of high inter-rater reliability?
4. **Results Are Used**. Assessment is a process designed to monitor and improve learning, so assessment findings should have an impact. Faculty should reflect on results for each outcome and decide if they are acceptable or disappointing. If results do not meet faculty standards, faculty should determine which changes should be made, e.g., in pedagogy, curriculum, student support, or faculty support. <u>Questions</u>: Do faculty collect assessment results, discuss them, and reach conclusions about student achievement? Do they develop explicit plans to improve student learning? Do they implement those plans? Do they have a history of securing necessary resources to support this implementation? Do they collaborate with other campus professionals to improve student learning? Do follow-up studies confirm that changes have improved learning?

The Student Experience. Students should understand the purposes different educational experiences serve in promoting their learning and development and know how to take advantage of them; ideally they should also participate in shaping those experiences. Thus it is essential to communicate to students consistently and include them meaningfully. <u>Questions</u>: Are purposes and outcomes communicated to students? Do they understand how capstones support learning? Do they participate in reviews of the capstone experience, its outcomes, criteria, or related activities?

PROGRAM REVIEW

Rubric for Assessing the Integration of Student Learning Assessment into Program Reviews

Criterion	Initial	Emerging	Developed	Highly Developed
Required Elements of the Self-Study	Program faculty may be required to provide a list of program-level student learning outcomes.	Faculty are required to provide the program's student learning outcomes and summarize annual assessment findings.	Faculty are required to provide the program's student learning outcomes, annual assessment studies, findings, and resulting changes. They may be required to submit a plan for the next cycle of assessment studies.	Faculty are required to evaluate the program's student learning outcomes, annual assessment findings, bench-marking results, subsequent changes, and evidence concerning the impact of these changes. They present a plan for the next cycle of assessment studies.
Process of Review	Internal and external reviewers do not address evidence concerning the quality of student learning in the program other than grades.	Internal and external reviewers address indirect and possibly direct evidence of student learning in the program; they do so at the descriptive level, rather than providing an evaluation.	Internal and external reviewers analyze direct and indirect evidence of student learning in the program and offer evaluative feedback and suggestions for improvement. They have sufficient expertise to evaluate program efforts; departments use the feedback to improve their work.	Well-qualified internal and external reviewers evaluate the program's learning outcomes, assessment plan, evidence, benchmarking results, and assessment impact. They give evaluative feedback and suggestions for improve-ment. The department uses the feedback to improve student learning.
Planning and Budgeting	The campus has not integrated program reviews into planning and budgeting processes.	The campus has attempted to integrate program reviews into planning and budgeting processes, but with limited success.	The campus generally integrates program reviews into planning and budgeting processes, but not through a formal process.	The campus systematically integrates program reviews into planning and budgeting processes, e.g., through negotiating formal action plans with mutually agreed-upon commitments.
Annual Feedback on Assessment Efforts	No individual or committee on campus provides feedback to departments on the quality of their outcomes, assessment plans, assessment studies, impact, etc.	An individual or committee occasionally provides feedback on the quality of outcomes, assessment plans, assessment studies, etc.	A well-qualified individual or committee provides annual feedback on the quality of outcomes, assessment plans, assessment studies, etc. Departments use the feedback to improve their work.	A well-qualified individual or committee provides annual feedback on the quality of outcomes, assessment plans, assessment studies, benchmarking results, and assessment impact. Departments effectively use the feedback to improve student learning. Follow-up activities enjoy institutional support
The Student Experience	Students are unaware of and uninvolved in program review.	Program review may include focus groups or conversations with students to follow up on results of surveys	The internal and external reviewers examine samples of student work, e.g., sample papers, portfolios and capstone projects. Students may be invited to discuss what they learned and how they learned it.	Students are respected partners in the program review process. They may offer poster sessions on their work, demon-strate how they apply rubrics to self-assess, and/or provide their own evaluative feedback.

How Visiting Team Members Can Use the Program Review Rubric

Conclusions should be based on a review of program-review documents and discussion with relevant campus representatives, such as department chairs, deans, and program review committees.

The rubric has five major dimensions:

1. **Self-Study Requirements**. The campus should have explicit requirements for the program's self-study, including an analysis of the program's learning outcomes and a review of the annual assessment studies conducted since the last program review. Faculty preparing the self-study should reflect on the accumulating results and their impact; and they should plan for the next cycle of assessment studies. As much as possible, programs should benchmark findings against similar programs on other campuses. Questions: Does the campus require self-studies that include an analysis of the program's learning outcomes, assessment studies, assessment results, benchmarking results, and assessment impact, including the impact of changes made in response to earlier studies? Does the campus require an updated assessment plan for the subsequent years before the next program review?
2. **Self-Study Review**. Internal reviewers (on-campus individuals, such as deans and program review committee members) and external reviewers (off-campus individuals, usually disciplinary experts) should evaluate the program's learning outcomes, assessment plan, assessment evidence, benchmarking results, and assessment impact; and they should provide evaluative feedback and suggestions for improvement. Questions: Who reviews the self-studies? Do they have the training or expertise to provide effective feedback? Do they routinely evaluate the program's learning outcomes, assessment plan, assessment evidence, benchmarking results, and assessment impact? Do they provide suggestions for improvement? Do departments effectively use this feedback to improve student learning?
3. **Planning and Budgeting**. Program reviews should not be *pro forma* exercises; they should be tied to planning and budgeting processes, with expectations that increased support will lead to increased effectiveness, such as improving student learning and retention rates. Questions. Does the campus systematically integrate program reviews into planning and budgeting processes? Are expectations established for the impact of planned changes?
4. **Annual Feedback on Assessment Efforts**. Campuses moving into the culture of evidence often find considerable variation in the quality of assessment efforts across programs, and waiting for years to provide feedback to improve the assessment process is unlikely to lead to effective campus practices. While program reviews encourage departments to reflect on multi-year assessment results, some programs are likely to require more immediate feedback, usually based on a required, annual assessment report. This feedback might be provided by an Assessment Director or Committee, relevant Dean or Associate Dean, or others; and whoever has this responsibility should have the expertise to provide quality feedback. Questions: Does someone have the responsibility for providing annual feedback on the assessment process? Does this person or team have the expertise to provide effective feedback? Does this person or team routinely provide feedback on the quality of outcomes, assessment plans, assessment studies, benchmarking results, and assessment impact? Do departments effectively use this feedback to improve student learning?
5. **The Student Experience**. Students have a unique perspective on a given program of study: they know better than anyone what it means to go through it as a student. Program review should take advantage of that perspective and build it into the review. Questions: Are students aware of the purpose and value of program review? Are they involved in preparations and the self-study? Do they have an opportunity to interact with internal or external reviewers, demonstrate and interpret their learning, and provide evaluative feedback?

The Educational Effectiveness Framework:
Capacity and Effectiveness as They Relate to Student and Institutional Learning

Key Descriptive Terms Ī Đ Element & Definition	INITIAL	EMERGING	DEVELOPED	HIGHLY DEVELOPED
Learning A. Student learning outcomes established; communicated in syllabi and publications; cited and used by faculty, student affairs, advisors, others (CFRs 2.2, 2.4):	For only a few programs and units; only vaguely (if at all) for GE; not communicated in syllabi, or publications such as catalogues, view books, guides to the major; only a few faculty know and use for designing curriculum, assignments, or assessment	For many programs and units, most aspects of GE; beginning to be communi-cated in basic documents; beginning to be used by some faculty for design of curriculum, assignments, assessments	For all units (academic & co-curricular), and for all aspects of GE; cited often but not in all appropriate places; most faculty cite; used in most programs for design of curriculum, assignments, and assessment	For all units (academic and co-curricular), and for all aspects of GE; cited widely by faculty and advisors; used routinely by faculty, student affairs, other staff in design of curricula, assignments, co-curriculum, and assessment
B. Expectations are established for how *well* (i.e., proficiency or level) students achieve outcomes (CFRs 2.1, 2.4, 2.5):	Expectations for student learning have not been set beyond course completion and GPA; level of learning expected relative to outcomes unclear	Expectations for level of learning explicit in a few programs; heavy reliance on course completion and GPA	Expectations for student learning explicit in most programs	Expectations for student learning are explicit in all programs, widely known and embraced by faculty, staff, and students
C. Assessment plans are in place; curricular and co-curricular outcomes are systematically assessed, improvements documented (CFRs 2.4, 2.7):	No comprehensive assessment plans. Outcomes assessed occasionally using surveys and self reports, seldom using direct assessment; rarely lead to revision of curriculum, pedagogy, co-curriculum, or other aspects of educational experience	Some planning in place. Outcomes assessed occasionally, principally using surveys; beginning to move toward some direct assessment; occasionally leads to improvements in educational experience; improvements sporadically documented, e.g., in units' annual reports.	Plans mostly in place. Assessment occurs periodically, using direct methods supplemented by indirect methods and descriptive data; educational experience is frequently improved based on evidence and findings; improvements are routinely documented, e.g. in units' annual reports	Assessment plans throughout institution. Assessment occurs on regular schedule using multiple methods; strong reliance on direct methods, performance-based; educational experience systematically reviewed and improved based on evidence and findings; documentation widespread and easy to locate.
D. Desired kind and level of learning is achieved (CFR 2.6):	Possible that learning is not up to expectations, and/or expectations set by institution are too low for degree(s) offered by the institution	Most students appear to achieve at levels set by the institution; faculty and other educators beginning to discuss expectations and assessment findings	Nearly all students achieve at or above levels set by institution; assessment findings discussed periodically by most faculty and other campus educators	All students achieve at or above levels set by institution; findings are discussed regularly and acted upon by all or nearly all faculty and other campus educators
Teaching/Learning Environment A. Curricula, pedagogy, co-curriculum, other aspects of educational experience are aligned with outcomes (2.1, 2.2, 2.3, 2.4, 2.5, 4.6):	Conceived exclusively or largely in terms of inputs (e.g. library holdings, lab space), curricular requirements (e.g., for majors, GE) and availability of co-curricular programs; not visibly aligned with outcomes or expectations for level of student achievement; evidence of alignment processes lacking	Educational experience beginning to be aligned with learning outcomes and expectations for student achievement; evidence of alignment efforts available in some academic and co-curricular programs	Educational experience generally aligned with learning outcomes, expectations for student achievement; alignment becoming intentional, systematic, supported by tools (e.g. curriculum maps) and processes. Evidence of alignment efforts generally available	Educational experience fully aligned with learning outcomes, expectations; alignment is systematic, supported by tools and processes as well as broader institutional infrastructure. Evidence of alignment efforts readily available
B. Curricular and co-curricular processes (CFRs 2.1, 2.2, 2.3, 2.11, 2.13) are:	Rarely informed by good learning practices as defined by the wider higher education community; few curricular or co-curricular activities reviewed, mostly without reference to outcomes or evidence of student learning	Informed in some instances by good learning practices; curricula and co-curricular activities occasionally reviewed and improved but with little reference to outcomes or assessment findings	Informed in many cases by good learning practices; reviewed and improved by relevant faculty and other campus educators; often based on outcomes and assessment findings	Regularly informed by good learning practices; improvements consistently result from scholarly reflection on outcomes and assessment findings by relevant faculty and other campus educators

C. Professional development, rewards (CFRs 2.8, 2.9):	Little or no support for faculty, other campus educators to develop expertise in assessment of student learning, related practices; work to assess, improve student learning plays no positive role in reward system, may be viewed as a negative	Some support for faculty, other educators on campus to develop expertise in assessment of student learning, related practices; modest, implicit positive role in reward system	Some support for faculty, other campus educators to develop expertise in assessment of student learning, related practices; explicit, positive role in reward structure	Significant support for faculty, other campus educators to develop expertise in assessment of student learning, related practices; explicit, prominent role in reward structure
Organizational Learning A. Indicators of educational effectiveness are (CFRs 1.2, 4.3, 4.4):	Notable by their absence or considered only sporadically in decision-making	Found in some areas; dissemination of performance results just beginning; no reference to comparative data	Multiple, with data collected regularly, disseminated, collectively analyzed; some comparative data used. Some indicators used to inform planning, budgeting, other decision making on occasional basis	Multiple, with data collected regularly, disseminated widely, collectively analyzed; comparative data used, as appropriate, in all programs. Indicators consistently used to inform planning, budgeting, other decision making at all levels of the institution
B. Formal program review (CFRs 2.7, 4.4) is:	Rare, if it occurs at all, with little or no useful data generated. Assessment findings on student learning not available and/or not used	Occasional, in some departments or units; heavy reliance on traditional inputs as indicators of quality; findings occasion-ally used to suggest improvements in educational effectiveness; weak linkage to institution-level planning, budgeting	Frequent, affecting most academic and co-curricular units, with growing inclusion of findings about student learning; unit uses findings to collectively reflect on, improve effectiveness; some linkage to institution-level planning, budgeting	Systematic and institution-wide, with learning assessment findings a major component; units use findings to improve student learning, program effectiveness, and supporting processes; close linkage to institution-level planning, budgeting
C. Performance data, evidence, and analyses (CFRs 4.3, 4.5, 4.6) are:	Not collected, disseminated, disaggregated, or accessible for wide use. Not evident in decision-making processes; do not appear to be used for improvement in any programs	Limited collection, dissemination, disaggregation, or access. Campus at beginning stages of use for decisions to improve educational effectiveness at program, unit, and/or institutional level	Systematic collection and dissemination, wide access; sometimes disaggregated; usually considered by decision-making bodies at all levels, but documentation and/or linkage to educational effectiveness may be weak	Systematic collection and dissemination, and access, purposeful disaggregation; consistently used by decision-making bodies for program improvement at all levels, with processes fully documented
D. Culture of inquiry and evidence (CFRs 4.5, 4.6, 4.7):	Faculty, other educators, staff, institutional leaders, governing board not visibly committed to a culture of inquiry and evidence except in isolated cases; not knowledgeable about learner-centeredness, assessment, etc.	Campus knowledge is minimal; support – at top levels and/or grass roots – for development of a culture of inquiry and evidence is sporadic and uneven	Campus knowledge and support for a culture of inquiry and evidence fairly consistent across administration, faculty, professional staff but may not be uniformly deep	Consistent, knowledgeable, deep commitment to creating and sustaining a culture of inquiry and evidence in all appropriate functions at all levels
E. Communication and transparency (CFR 1.2, 1.7):	Little or no data, findings, analyses from assessment of student learning available within the institution or to external audiences	Some data, findings, analyses from assessment of student learning available but may be incomplete, difficult to access or understand for internal or external audiences	Data, findings, analyses from assessment of student learning generally available, easily accessible; chosen for relevance to multiple audiences	Data, findings, analyses from learning assessment are widely available and skillfully framed to be understandable, useful to multiple audiences
Overall: The institution can best be described as:	Committed to isolated aspects of educational effectiveness; if other areas are not addressed, continuing reaffirmation of accreditation is threatened	Committed to educational effectiveness in some areas; significant number of areas require attention, improvement	Mostly well-established commitment to educational effectiveness; a few areas require attention, improvement	Fully committed to and going beyond WASC recommendations; operates at an exemplary level in addressing its Core Commitments to capacity as it relates to learning and to educational effectiveness

WASC Senior College and University Commission | EDUCATIONAL PROGRAMS

Selected Readings on Quantitative Reasoning and Assessment in Majors

Literature on Assessing Student Learning in Academic Majors and Quantitative Reasoning

Allen, M.J. (2004). *Assessing academic programs in higher education*. Bolton, MA: Anker.

Angelo, T. A., and Cross, K. P. (1993). *Classroom assessment techniques: A handbook for college teachers* (2nd ed.). San Francisco, CA: Jossey-Bass.

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Disciplinary Samples

http://assessment.voices.wooster.edu/disciplines-2/

http://www.assessmentupdate.com/sample-articles/disciplinary-resources-assessment-liberal-arts.aspx

http://assessment.georgetown.edu/wp-content/uploads/Disciplinary-Associations-Assessment-Resources.pdf

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Online Resources for Assessment and Quantitative Reasoning

AAC&U's Assessment Resource page: http://www.aacu.org/resources/assessment/index.cfm

AAC&U VALUE Rubric on Quantitative Literacy: http://www.aacu.org/value/rubrics/Quantitative Literacy.cfm.

Bowdoin College's Quantitative Skills Program: http://www.bowdoin.edu/qr-program/index.shtml.

Dartmouth College's Mathematics across the Curriculum: http://www.dartmouth.edu/~matc/Evaluation/humeval.pdf

National Numeracy Network (NNN): http://serc.carleton.edu/nnn/index.html.

Numeracy journal: http://scholarcommons.usf.edu/numeracy/

Mathematics Association of America: http://www.maa.org/programs/faculty-and-departments/curriculum-department-guidelines-recommendations/quantitative-literacy

Mathematical Literacy: https://sites.google.com/a/dpi.wi.gov/disciplinary-literacy-in-mathematics/

Project Kaleidoscope (PKAL): http://aacu.org/pkal/resources/teaching/quantitative.cfm

Quantitative Learning and Reasoning Assessment instrument: http://serc.carleton.edu/qlra/index.html

Quantitative Reasoning Test: http://www.madisonassessment.com/assessment-testing/quantitative-reasoning-test/Science Education Resource Center's Teaching with Data Website: http://serc.carleton.edu/sp/library/twd/index.html

Science Education Resource Center's Teaching Quantitative Reasoning Website: http://serc.carleton.edu/sp/library/qr/index.html

SERC websites on Assessment of QR: http://serc.carleton.edu/NICHE/ex_qr_assessment.html.

WASC Senior College and University Commission

Assessment Leadership Academy

An Opportunity for Your Campus to Develop Assessment Expertise and Leadership
March 2015 - January 2016

Application Deadline: February 15, 2015

Purpose of the Academy
The **WSCUC Assessment Leadership Academy (ALA)** prepares postsecondary professionals to provide leadership in a wide range of activities related to assessment of student learning, from facilitating workshops and supporting the scholarship of assessment to assisting administrative leadership in planning, budgeting, and decision-making related to educational effectiveness. ALA graduates have also provided consultation to the WSCUC region and served on WSCUC committees and evaluation teams; some have moved on to new positions with greater responsibilities. The Academy curriculum includes both structured and institutionally-tailored learning activities that address the full spectrum of assessment issues and places those issues in the national context of higher education policy on educational quality, accreditation, and accountability.

Who Should Participate in the Academy?
Higher education faculty, staff, and administrators who are committed to:

- Developing assessment expertise
- Serving in an on-going assessment leadership role at their institution
- Devoting significant time to complete ALA reading and homework assignments

Assessment Leadership Academy Faculty
ALA participants will interact with and learn from nationally-recognized higher education leaders. Faculty and Co-Facilitators of the ALA lead interactive class sessions and are available to participants for one-on-one consultations.

Faculty and Co-Facilitators of the ALA:
- **Mary J. Allen**, Former Director of the CA State University Institute for Teaching & Learning
- **Amy Driscoll**, Former Director of Teaching, Learning, and Assessment, CSU Monterey Bay

Guest Faculty Have Included:
- **Trudy Banta**, Senior Advisor to the Chancellor for Academic Planning and Evaluation, IUPUI
- **Marilee Bresciani**, Professor of Postsecondary Education Leadership, San Diego State University
- **Peter Ewell**, Vice President, National Center for Higher Education Management Systems
- **Adrianna Kezar**, Associate Professor for Higher Education, University of Southern California
- **Jillian Kinzie**, Associate Director, Center for Postsecondary Research & NSSE Institute
- **Kathleen Yancey**, Kellogg W. Hunt Professor of English, Florida State University

Learning Goals
Participants who complete Academy requirements will acquire foundational knowledge of the history, theory, and concepts of assessment; they will also develop expertise in training and consultation, campus leadership for assessment, and the scholarship of assessment.

Application Process and Deadline
Each year about 30 professionals are admitted. Participants are selected through an online application process. Applications for the 2015-16 class will be accepted from November 15, 2014 until February 15, 2015.

More Information
For more information and application materials, please see **Assessment Leadership Academy** on the WSCUC website http://www.wascsenior.org/ala/overview

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