Report of the Science Literacy sub-committee

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I. Introduction

We are routinely confronted by scientific claims, innovations and interpretations that collectively challenge our sense of identity (e.g., new ways to understand our origins, development, cognition, genetic predispositions, and addictions), terrify us (e.g., claims regarding our environment, our capacity to destroy, an apocalypse), help us perceive worlds hitherto unimagined (e.g., the nature of the cosmos, our precise position on earth *as seen from space*, molecular imaging, lives extended by decades due to modern medicene), and act as the foundations for our experiences as social organisms in the modern world (e.g., network structure, paternity analysis). We infer pattern, evaluate the causative links between phenomena (chance or cause and effect?), draw conclusions regarding the future (e.g., calculate probability, acceptable risk, and compounded interest), and have access to a magnitude of quantitative information regarding virtually any topic that is unprecedented within human history. Furthermore, we ourselves create this quantitative information – in many instances, we are the data being explored and described.

Nevertheless, many undergraduates do not appreciate the relevance of science and mathematics to their own lives. Some doubtlessly perceive contemporary scientists as keepers of vast stores of factual knowledge, rather than as seekers and guides to a clearer understanding of how the world around us works (Meinwald and Hildebrand 2010). The disciplines are understood to be overly specific or overly abstract, to the point that the applications of any learning are unclear. As a result, students may be less willing and less able to participate in the dialogues that profoundly affect them. *Literacies*, whether scientific or quantitative, are contextualized - they describe an ability to apply modes of thinking to "real world" situations (e.g., Bray-Speth *et al*. 2010) and to appreciate the intricate relationships between the disciplines and society (Ebert-May *et al*. 2010). Literacy, and the attendant proficiencies, prepares the mind to construct reasoned arguments when participating in the aforementioned dialogues, to apply pre-existing knowledge of natural phenomena and the nature of scientific inquiry, and to communicate arguments in a manner that can be understood and evaluated by others. These literacies are cultivated and reinforced by use over time. They should become true habits of mind, incapable of being memorized or forgotten.

Scientific literacy has the potential to substantiate many of the core elements of the College's *Goals for Student Learning and Development*. Elements particularly relevant to Science Literacy are linked to student **knowledge** (e.g., "Acquire knowledge of human cultures and the physical world"; "Demonstrate advanced leaning and synthesis in both general and specialized studies"), **intellectual skills and practices** ("Think critically, creatively and independently", "Gather, analyze, integrate and apply varied forms of information; understand and use evidence", "Communicate effectively"), **personal and social values** ("Develop practical competencies for managing a personal, professional and community life", "Apply learning to find solutions for social, civic and scientific problems") and **Transformation** ("Integrate and apply knowledge and creative thought from multiple disciplines in new contexts", "Embrace intellectual integrity, humility and courage", "Foster habits of mind and body that enable a person to live deliberately and well", "Develop and enduring passion for learning").

A Scientific Literacy that includes these elements is not a discipline. It is a habit of mind, reinforced and supported by content and context. A conventional modular curriculum and conventional all-college requirements may be ill suited, in some respects, for cultivating that literacy. Who is responsible for cultivating this literacy? What is the role of collaboration and synthesis in this work? How can learning be assessed, and how can evidence derived from assessment be applied towards remedying perceived deficiencies? Below, we introduce a definition for scientific literacy, identify the congruence between the elements in this definition and the existing all-college requirements for Quantitative Reasoning and proficiencies in the Natural Sciences, evaluate the evidence that literacy (as defined) needs to be differently supported at the College, and offer recommendations for that support.

II. A Description of Scientific Literacy

We believe that *all* Skidmore students should possess basic scientific literacy, which we see as having <u>three</u> primary components. All Skidmore students should:

- Have knowledge and understanding of scientific methodologies, concepts, and processes inasmuch as these are relevant to personal decision-making, participation in civic and cultural affairs, economic productivity, and to developing effective responses to our rapidly changing natural and cultural environments.

- Have the ability to ask, find, determine, and communicate answers to questions about everyday experience using scientific methodologies appropriate to the phenomenon that is desired to be understood.

- Have the ability to make appropriate use of as well as critique scientific information as presented to the general public. More specifically, scientific literacy entails being able to understand articles about science in the popular press and to effectively engage in conversation about the validity and relevancy of the conclusions. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately.

This definition directly incorporates language from the text *National Science Education Standards: observe, interact, change, learn* (National Research Council, 1995; pp 22).

III. The relationship between science literacy and the existing all-college Quantitative Reasoning and Natural Science requirements.

Natural Science Requirement - The natural science requirement (NR) is linked to Scientific Literacy (hereafter SL) but the two are not the same. Students satisfy the NR breadth requirement by exploring a discipline in the natural sciences in a course with an associated weekly laboratory module. Beyond the exploratory nature of the requirement, it is a means to help students experience the scientific method in action in a laboratory or field setting. The experience complements the desired SL learning outcomes but does not necessarily address those outcomes in depth. Although students in NR courses begin to engage and critique scientific information and to apply scientific methodologies, this typically occurs within the confines of a focused area of study. For example, the mission of the course is to provide a foundational introduction to the relevance of that particular natural science discipline in solving problems appropriate to the discipline. What is not required, and may be missing in some courses, is a broader perspective of science as collective human endeavor to understand how the universe works, as well as an appreciation of the challenges and limitations that come from science as a human enterprise.

Most students at Skidmore fulfill their NR by taking an introductory course for majors in a particular scientific discipline (78 % of students in the 2009-2011 graduating classes, Appendix B). These courses, in particular, are designed to introduce key concepts, language, and skill sets to be used in more advanced science courses. In the process, students are exposed to developing a hypothesis, experimentation, quantitative data analysis, and making appropriate conclusions based on the results all in a particular context. As a result, students in NR courses experience the desired outcomes articulated in the existing breadth requirement. However, in many courses there is not time to have students grapple with the larger concepts at the heart of the SL learning outcomes, except at a superficial level. We do not expect that the content, context and pedagogical practices deemed appropriate for the development of self-selecting majors within a discipline is equally well suited for cultivating a layperson's appreciation of the relevance of that discipline and the sciences in general. That is not to say that NR and SL cannot overlap in a course designed to support both those aims. For example, it is very likely ES 105 could fulfill the NR and SL learning outcomes. SL themes and outcomes also seem evident in the existing NR courses for non-science majors (*e.g.*, the PY 103-194 and BI 110-180 offerings).

Quantitative Reasoning - Having the ability to engage, critique and apply scientific information and concepts in a meaningful way requires a certain level of sophistication in quantitative reasoning skills. The description for the existing quantitative reasoning (QR) requirement is provided in Appendix C. The QR1 is a first step in ensuring that students have the knowledge and abilities that is a pre-requisite to be scientifically literate. One concern with the current QR2 requirement (Appendix C) is that, in most cases, it does not follow through on these same skills. As is the case with some all-college requirements, the present QR2 requirement is more experientially based than outcomes based. Many of these experiences have little or nothing to do with ensuring that students can effectively comprehend or interrogate the scientific validity of an argument at even a basic level. In addition, QR alone does meet the full breadth of SL but is rather one of the competencies needed to be a scientifically literate citizen. As with NR, certain courses (e.g., statistics) could allow students to develop their quantitative reasoning skills in the context where they meet the broader SL learning outcomes.

Some basic recommendations concerning the interplay of the QR requirement and the above SL learning outcome are to:

- Assess the current QR requirement, particularly QR2, in regard to whether it is achieving identified goals.
- Determine student-learning outcomes for QR that align with the SL student-learning outcomes.
- If we keep the current QR1+QR2 requirement, reexamine the rigor of the QR1 requirement and require every QR2 course to be recertified in light of the learning goals that are designed.

IV. Evidence that scientific literacy needs to be supported differently at the College

Information from the National Study of Student Engagement (NSSE), the 2006 Middle States report, and Skidmore's Office of Institutional Research were used to infer the views and experiences (enrollment patterns for classes of 2009, 2010 and 2011) of Skidmore students. Further information and interpretation is included in Appendices B and D.

- When asked to "identify the extent to which experiences at their institution contributed to their knowledge, skills and personal development in *analyzing quantitative problems*" (Source: NSSE), Skidmore students are consistently less likely to detect or endorse contributions in quantitative literacy made in their first year, relative students from peer institutions. Further, **a smaller fraction of Skidmore seniors in 2003, 2007 and 2010 reported that their college experiences contributed "very much" to their ability to analyze quantitative problems, relative to our peers**. One explanation is that more than 80% of current students demonstrate the rudimentary proficiency identified in the QR1 requirement by "testing out" of the requirement (i.e., they do not enroll in a course to fulfill the QR1 requirement).
- Based on results in the 2006 Middle States report, **only a narrow majority of Skidmore students consider science a form of creative thought and found it easy to make connections between science course and other work. A mere 16% agreed with the assertion that an understanding of science is essential for an engaged citizen**.
- **The experiences in gateway courses in the sciences are unlike those in other disciplines.** Some of these differences, such as an associated 1-credit laboratory experience that meets for 2-3 hours per week and typically includes less than 16 students per section, doubtlessly strengthen the courses. However, the typical student experience in a 100-level natural science or mathematics course also involves a common lecture with many students. Specifically, 50% of the student enrollments at the 100-level occur in courses with more than 34 students in the common lecture (duration: 2009-2011), a number substantially greater than that experienced in 100-level courses in the Humanities, Visual and Performing Arts, and the Social Sciences (16, 19 and 27 students, respectively). A quarter of the total enrollments place students in 100-level courses with with 65 students or greater – a number largely unprecedented in the other three divisions. More than 70% of the non-scientists (i.e., students that go on to become majors or minors in other disciplines) satisfy the NR requirement in courses designed to support science majors in the department offering the course. Although NR-satisfying courses designed for the layperson are offered by some departments (see above), the courses are smaller and have capped enrollments, and hence often enroll to capacity. Hence, the typical student experience does not occur in this setting.
- **Most students report a lack of interest in taking an additional science course beyond what is currently required** (Source: Middle States), and the average number of NR courses taken by students that are not science majors or minors is 1.2 (Source: Institutional Research).

V. Strategies to foster Scientific Literacy and expected outcomes.

The **outcomes** we expect to follow an encouragement of scientific literacy at the College will include: a) a more humanistic understanding of science and its relationship to students' lives; b) a diminished 'fear' of science for non-science majors; c) an increase in the ability of science majors to understand and communicate the relevance of science to other fields and topics; d) an enhancement of the potential to voluntarily integrate perspectives/interests across disciplines among *both students and faculty*; and e) a potential to generate a new sense of campus community and civic engagement that arises by addressing science 'problems' of common interest and developing tools for decision making.

The following list identifies **potential areas to foster new science literacy activities** at the College. We position these strategies within four settings: the curriculum, programming, communications and facilities. The sub-committee concluded that science literacy can be a learning goal that is not predicated on proficiency in other disciplines. We also recognized that the College may be best positioned to effectively and creatively support science literacy in instances where it is linked to other disciplines. As a result, many practices that support science literacy also likely foster the integration the disciplines and likely vice versa. Bearing this in mind, the following list also identifies potential strategies to more fully integrate the sciences with the arts, humanities and social sciences. Appendix E provides a fuller description of possible models in the Curriculum, and Appendix F provides a fuller description of the components of the list below.

In the curriculum:

- Consider various models that address science literacy in either existing courses or through new course experiences. These might include:
    - Collaborative Problem Solving Across Disciplines
    - 1-2 credit add-on interdisciplinary experience
    - 1-2 credit add-on to NR course
    - Stand-alone science literacy
    - Traditional 3 or 4 credit course
    - Create a Science Literacy requirement
- Establish a timeslot during the week when classes are NOT scheduled to encourage and allow for interdisciplinary projects.

In programs:

- Using existing programs, consider ways to support more interdisciplinary collaboration surrounding science with an intent to foster a different appreciation for science literacy. These might include:
    - an option for teams of faculty to collaborate in summer student collaborative research;
    - targeting a Tang Mellon seminar to address science;
    - expanding study abroad and internships that focus on science, paired with regular student forums for presenting these experiences to other students.
- Establish a regular Scientific Literacy speaker event.
- Establish new faculty positions at the intersection of disciplines.

In communications:

- Recognize both students and alums working at the intersections of the sciences and the arts, humanities and social sciences.
- Recognize faculty achievements working at the intersections of the sciences and the arts, humanities and social sciences.
- Work with faculty and communications staff to insure accurate reporting and representation, as well as considering ways to make sharing new projects and achievements easier.

In the facilities:

- Develop collaborative research spaces. Make spaces that support adjacencies for science in strategic locations, both in science buildings as well as in non-science buildings.
- Utilize existing spaces and, if necessary, create new spaces to address the relevance and communication of science literacy.

VI. Recommendations

Identify prospective scientific literacy "hotspots" in the curriculum. A definition of scientific literacy should be introduced to the faculty and staff of the College. Thereafter, the faculty should be surveyed to identify courses that are believed (by the instructors, as well as perhaps by a second "vetting" party) to satisfy at least one of the three criteria for science literacy. Such courses will be identified with a SL designation that will serve multiple purposes. The designation helps students and faculty advisors identify the learning goals or experiences of particular courses, and, in doing so, may help students find and re-enroll in a suite of SL designated courses. SL content should change the ways students understand their previous or ongoing experiences (courses) in the natural sciences and math, and should change the way they approach and frame subsequent courses in those and other disciplines (see below in Assessment). The SL designation should also help the faculty to identify literacy-themed courses taught by their colleagues. In some cases, the SL courses will have more in common, pedagogically speaking, with one another than with other courses in the home discipline. For example, a SL course and an introductory course designed for nascent majors likely have different learning goals and serve largely non-overlapping sets and types of students. A faculty group (formal or otherwise) that includes the instructors of SL courses could be beneficial and invigorating to many.

To be clear, this SL designation involves self-identification by the instructors of the courses. The presence of that designation could be provided to the Registrar's office, but the application for that designation should not involve Curriculum Committee and nor should it be interpreted or presented as an all-college requirement (at this time).

Assess existing scientific literacy throughout the College. Assessment is needed to evaluate the current state of science literacy at the College, help articulate the various components of science literacy in both the curriculum and outside of the classroom, and quantify changes in these areas moving forward. We identify two main areas for assessment:

- *Student Assessment* – To assess the student experience in relation to SL, we propose two forms of assessment. The first describes students' experiences at Skidmore in relation to SL. Ideally, the surveys would be coded to allow for monitoring of changes at the individual level while maintaining student anonymity. This coding would help describe changes in SL over time and make it possible to parse the idiosyncrasies of each student (e.g., differences in initial interest or understanding). Richard Carrier's Scientific Literacy Test (http://www.infidels.org/library/modern/richard_carrier/SciLit.html) asks students to answer whether a series of statements about science are true or false, and it may a model to assess the first component. The second form of assessment would get at the SL learning outcomes, including the students' understanding of the scientific enterprise and their ability to critique case studies. This second stage of assessment could ask students to read articles from media sources directed at the general public, and to explore their ability to draw appropriate scientific conclusions and critiques of the articles. Both forms of assessment would ideally be performed at the start and end of a student's career at Skidmore as well as at level of individual courses in some settings (*e.g.*, at the start and end of an NR, QR2 or SL-designated course). The assessment should also be tied to evaluation of the QR experience (see above). The change over the course of a class, as well as over the arc of the Skidmore experience, will better pinpoint when and how well we are preparing out students to be scientifically literate citizens.

- *College Assessment* – To assess scientific literacy across the College we propose to survey the faculty (broadly) and staff of programs that relate to SL. Although some programs and departments have conducted assessment relevant to this topic previously, it would be helpful to have campus-wide targeted, uniform data moving forward. The primary themes to assess should include:
  - attitudes towards scientific literacy;
  - resources that support scientific literacy;
  - locating where scientific literacy is addressed in the current curriculum;
  - the perceived outcome of any implemented changes.

Overall, these data would be used understand the current climate of scientific literacy at the College, and then evaluate change over time. As stated in the *2008-2018 Science Vision* document, pedagogical opportunities outside of the classroom may provide valuable scientific literacy engagement, such as collaborative research, interdisciplinary exhibitions at the Tang, and internships. Faculty interest and the perceived ability to participate in these types of opportunities would be assessed through this survey. The results would help identify new ways to foster scientific literacy at the College.

A word about Double Counting

Students are very adept at identifying courses that satisfy multiple requirements, and some faculty lament this phenomenon. Scientific Literacy might be most effectively enhanced if, in this particular context, we embrace the penchant for double dipping. We want students to intentionally link the content and modes of thinking cultivated in different disciplines. We want faculty (and clusters of faculty) to be cognizant of how they can help students develop these skills and to appreciate the relevancy of that interplay in other aspects of their lives and intellectual pursuits.

References

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Appendix A
CEPP CHARGE TO A SCIENCE LITERACY SUB-COMMITTEE

CEPP will create a sub-committee to explore science literacy as an emerging strategic theme for the College. In particular, the sub-committee shall identify the relationships among learning goals for science literacy articulated in the Strategic Plan, the Science Vision, and the learning goals the faculty has set forth for the students within the scope of their inclusive college education that include:

- Acquire knowledge of human cultures and the physical world through study in the arts, humanities, languages, mathematics, natural sciences, and social sciences;
- Demonstrate advanced learning and synthesis in both general and specialized studies;
- Gather, analyze, integrate, and apply varied forms of information; understand and use evidence;
- Develop practical competencies for managing a personal, professional, and community life;
- Integrate and apply knowledge and creative thought from multiple disciplines in new contexts.

CHARGE: CEPP charges this subcommittee with assessing the theme of Science Literacy in the following ways:

- Define *science literacy* in a manner that can be broadly understood and assessed;
- Evaluate the argument that science literacy needs to be enhanced within the College; and identify the outcomes expected to follow an encouragement of scientific literacy;
- If deemed necessary, identify new ways to foster and assess science literacy;
- Clarify the relationship between science literacy and the aspiration to foster a more substantive and distinctive integration of the sciences with the arts, humanities and social sciences;
- Identify the relationship between science literacy and the existing all-college Quantitative Reasoning and Natural Science requirements.

CEPP recommends that the sub-committee consult current scholarship, appropriate committees and other college bodies (e.g., Curriculum Committee, SGA), and colleagues with various perspectives and expertise on, and interest in, science literacy. The sub-committee will convene during the spring semester of 2012 and submit a final report with recommendations to CEPP by the end of the spring semester – the week of May 2nd.

Appendix B. Data that relate to the NR requirement in particular.

To describe when students enroll in these courses, and the relative enrollment in courses of the two types, we sought information from the Office of Institutional Research regarding the graduating classes of 2009, 2010 and 2011. As a whole, these three classes included 422 science majors, 20 science minors (i.e., science minors paired with a non-science major), and 1234 non-science majors. For the purposes here, Math and Computer Science majors were coded as non-scientists – the logic being that these students cannot fulfill their NR-requirement with a course required for their major. The 62 Environmental Studies majors, a group that can include both scientists and non-scientists (due to the parallel *Science* and *Social and Cultural* tracks in the major), were coded separately from the science majors, science minors, and non-scientists, and are not included in the summary below.

***When** do students satisfy their NR requirements?* The proportion of all students (irrespective of major or minor) that have satisfied the requirement (shown in filled squares in Fig. 1) increases from 40% to 72% to 90% across their first three years at Skidmore. Students that become science majors and minors satisfy their NR requirements early in their career at Skidmore. Perhaps surprisingly, science minors as a group satisfy the requirement slightly earlier than do science majors (95% and 83% within first two years, respectively). The non-science majors satisfy the requirement more slowly – 31% as first-years, 35% as sophomores, 21% as juniors, and 12% as seniors. Ten of 1234 non-scientists satisfied the NR requirement during a fifth year.

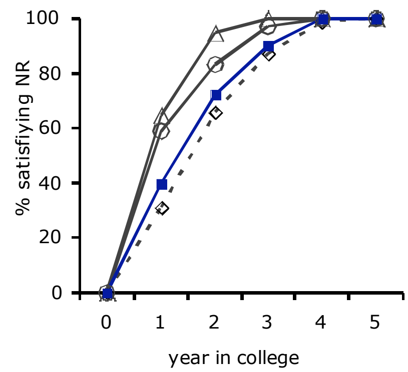

Fig 1. Proportion of students that have satisfied the NR requirement.

***How many** NR courses do students take?* The NR requirement is satisfied by one course, although students can enroll in more than one NR-accredited course over the arc of their undergraduate career. The grand average per student for the 2009-2011 classes is 2.0 NR courses, although this average may be misleading. For example, the average number of NR courses taken by science majors and science minors is 3.9, 3.3, and, with the exception of Psychology, each of the science majors and minors require multiple courses that satisfy the NR requirement (e.g., a Biology major requires BI105, BI106 and some combination of CH105, CH106 and CH107). The average number of NR courses taken by non-scientists 1.2. As a result, because most students (1234 of 1738) are non-scientists, typical enrollment is low - rarely more than one course for a non-scientist.

***What sorts** of NR courses do the students experience?* For the purposes of the forthcoming analyses, NR courses were divided into two categories: 1) those that count towards the major in the dept/program offering the course and 2) those that do not (hereafter type 1 and 2, respectively). These can be envisioned as "courses for scientists" (BI105, BI106, CH105, CH106, CH107, CH 112, ES105, EX111, EX126, EX127, GE101, GE102, GE112, GE211, NS101, PS306 and PY207) and "science-rich courses for the layperson" (BI110, BI115, BI120, BI140, BI150, BI165, Bi170, CH103, CH 110, PY103, PY106, PY107, PY109 and PY194). The comparable number of courses in these two categories (20 and 14, respectively) implies a rough equivalency in offerings for students. In fact, the total number of student seats (occupied seats) in the type 1 and type 2 courses was 2980 and 457 (respectively) in 2009-2011. As a consequence of, 87% of the enrollments in NR-satisfying courses experienced by the graduating classes of 2009-2011 occurred in type 1 courses.

Because some of these NR-designated courses are predicated on participation in an earlier NR-satisfying course (e.g., Bi106 has a pre-requisite of Bi105), a more accurate description of the ways students satisfy the NR requirement requires identifying the first NR course a student enrolls in. In 1348 of the 1739 (78%) incidents in which students satisfied the NR requirement, they did so in a type 1 course. The rank order of NR-satisfying enrollment is: Biology courses (22.8% of total), Geosciences courses (22.2%), Exercise science courses (14.7%), Physics courses (11%), NS 101 (8.5%), Chemistry courses (8.1%) and PS306 (5.3%) (see table).

Course	Title	Type	NR satisfied seats	% total
BI-105	Biological Sciences I	1	182	10.5
BI-110	Biology of the Mind (w/ Lab)	2	82	4.7
BI-115H	Ecology of Food	2	14	0.8
BI-120	The Human Organism	2	1	0.1
BI-140	Marine Biology	2	84	4.8
BI-150	Study of Life	2	2	0.1
BI-165	Microbes and Society / Food Microbiology	2	6	0.3
BI-170	Human Genetics	2	26	1.5
CH-103	Fund of Chemistry w/Lab	2	27	1.6
CH-105	Chem Principles I w/Lab	1	86	4.9
CH-105H	Hon:Chemical Prin I	1	5	0.3
CH-107H	Intensv Gen Ch: Honors	1	11	0.6
CH-110	Chem of Foods (W/ Lab)	2	2	0.1
CH-112	Envir Chemistry (W/Lab)	1	9	0.5
ES-105	Fld Studies Environ Sci	1	128	7.4
EX-111	Intro to Exer Science	1	220	12.7
EX-126	Human Anat and Physio I	1	35	2.0
EX-127	Human Anat and Physio II	1	1	0.1
GE-101	Earth Systems Science	1	190	10.9
GE-102	History of Earth and Life	1	95	5.5
GE-112	Intro to Oceanography	1	92	5.3
GE-211	Climatology	1	9	0.5
NS-101	Intro to Neuroscience	1	147	8.5
PS-306	Experimental Psychology	1	93	5.3
PY-103	Origins Classical Phys	2	9	0.5
PY-106	Breakthroughs in Physics w/Lab	2	4	0.2
PY-107	Light and Color	2	16	0.9
PY-109	Sound and Music w/ Lab	2	74	4.3
PY-194	Prin and Pract Astro Wlab	2	44	2.5
PY-207	General Physics I w/Lab	1	41	2.4
PY-208	General Physics II	1	4	0.2

How do scientists and non-scientists satisfy their NR requirements? An overwhelming majority of science majors and science minors (94% and 95%, respectively) satisfy their NR requirement (i.e., take their first NR accredited course in) a type 1 course that can counts towards a science major. Further, only 3% of all NR courses taken by science majors and minors were of the type 2 variety. Most non-science majors (71%) satisfied the NR requirement in type 1 courses, although that group also accounted for 360 of the 391 seats (92%) in type 2 courses. Further, those type 2 NR courses accounted for 26% of all NR courses taken by non-scientists.

What types of courses are used by the students that do enroll in NR courses after satisfying the NR requirement? Perhaps surprisingly, type 1 NR-courses (foundational courses for a science major) may make up a greater proportion of the NR-satisfying courses that students enroll in after satisfying the requirement (i.e., scientific content increased). The proportion of NR courses that are type 1 stays consistent for science majors and science minors (97% and 97% for satisfying the requirement, 98% and 98% for subsequent courses) and increases for the non-scientists (74% for satisfying the requirement, 91% for the successive courses). Notably, this change for the non-scientists likely occurs even when they have greater latitude to choose courses (due to links between maturity, registration periods and seat availability).

Appendix C. Guidelines for the existing Quantitative Reasoning Requirement.

Quantitative Reasoning 2. Courses designated as satisfying the second stage of the QR requirement build upon the skills that students have mastered in QR1 (i.e., arithmetic, consumer issues, practical geometry, linear equations and linear growth, compound interest and exponential growth, data presentation and description, and basic probability and statistics). This can be accomplished in two ways (or a combination). First, a QR2 course might expand upon the ideas from QR1 in an applied setting, permitting students to see, in more depth, how these tools are used to solve problems in a specific discipline (or disciplines). Second, a QR2 course might build upon the skills covered in QR1 by increasing the breadth of quantitative skills that a student has mastered. In either case, QR2 courses will include the study of quantitative skills as a central and indispensable aspect of the course. The breadth, and/or depth, and the level of sophistication in a QR2 course should be above that of QR1, requiring students to master quantitative skills that are truly at the college level. Such skills might include, for example, one or more of the following:

a. Study of rates of change in various systems with the aid of numerical methods, the calculus, and/or differential equations.

a. The study of forms and shapes with the aid of geometry.

a. The study of system behavior, competition, game strategies, and/or decision making, with the aid of probability theory.

a. The study of measurement, data collection, cause and effect relationships, and/or patterns with the aid of statistical methods.

a. The study of system properties that are expressed and evaluated with the aid of algebra.

a. The study of resource allocation, planning and scheduling with the aid of linear programming.

Courses that satisfy the QR2 requirement need not necessarily exhibit a computing component, but its inclusion can enrich the content of the course. For example, the use of computers is encouraged to automate computation, test algorithms, and build and assess the validity of models of complex quantitative systems.

Appendix D. Data that relate to student interest and perceptions

The National Study of Student Engagement (NSSE) asks students to "identify the extent to which experiences at their institution contributed to their knowledge, skills and personal development in *analyzing quantitative problems"*. This question was posed to first-year and senior students in 2003, 2007 and 2010 at Skidmore and peer institutions. It is a challenging question to interpret (does it measure absolute proficiency or changes in proficiency? Real or perceived?). The data is organized below in a fashion meant to facilitate comparisons between incoming first-year students and the seniors they collectively become for the 2003-2007 and 2007-2010 increments (see table 1). One observation is that Skidmore students are consistently less likely to detect or endorse contributions made in their first year, relative students from peer institutions. Skidmore also seems to be making more "progress" over the four year span than are our peers, if progress is defined as decreasing the fraction of students that responded "very little" or "some" to this questions over the four year span (e.g., comparing the first year student in 2007 with the senior in 2010). One related issue involves the timing in which students satisfy their QR requirements. A first year student that tested out of QR1 (as do most students) and has yet to take a QR2 course might accurately conclude that the college has not yet contributed to their ability to analyze quantitative problems. Nonetheless, a smaller fraction of Skidmore seniors in 2003, 2007 and 2010 reported that their experiences contributed "very much" to their ability to analyze quantitative problems, relative to our peers. Irrespective of whether the question is interpreted as relating to absolute or relative changes in proficiency, that sustained difference is a concern.

Table 1.

SKIDMORE	Group	very little	some	quite a bit	very much
2003	seniors (2003)	10	36	34	19
2003-2007	first years (in 2003)	12	45	33	9
	seniors (in 2007)	10	36	31	23
2007-2010	first years (in 2007)	12	33	35	21
	seniors (in 2010)	7	25	36	32
2010	first years (in 2010)	7	31	40	22
PEERS	Group	very little	some	quite a bit	very much
2003	seniors (2003)	8	29	33	29
2003-2007	first years (in 2003)	11	32	37	21
	seniors (in 2007)	6	23	33	37
2007-2010	first years (in 2007)	8	27	37	28
	seniors (in 2010)	5	23	34	38
2010	first years (in 2010)	5	22	40	33

The 2006 Middle States report includes responses to a survey administered in April 2005 to 378 first-year students and sophomores. The survey included queries related to the students' perception of the sciences, and the results are shown in Table 2. A concise summary is that a narrow majority of students report that they enjoyed taking a science course to fulfill their breadth requirement, consider science a form of creative thought, and found it easy to make connections between science course and other work, and that only 16% of the respondents agree with the assertion that an understanding of science is essential for an engaged citizen. Our subcommittee is not aware of Middle States data that quantifies the students' enjoyment of other breadth requirements, whether those other requirements are deemed to support creative thought, or whether understanding of those fields are deemed an essential characteristic for an engaged citizen. The subcommittee was also unsure how the engaged citizen question (#17 in table 2) was perceived by the students. Many would dispute the assertion that understanding is a necessary *precondition* to being an engaged citizen, even as they would also agree with the assertion that an understanding of science supports greater participation, enhances an individual's ability to participate in those discussions in a more substantive fashion, and increases the ability to substantively engage with a variety of issues that concerns citizens and for which they are asked to cast votes. The subcommittee was also unsure whether the question adequately captures the distinction between the "process of science" and scientific content (e.g., a knowledge of the fundamental phenomena of nature). We expect our students to understand why the sun rises and sets, but that does not mean that understanding planetary orbits is a requirement for engaged citizenship.

Table 2. Middle States 2006 student survey responses. Response percentages shown, and question numbering is preserved from the Middle States report.

Question	Disagree strongly	Disagree	Not sure	Agree	Agree strongly
15. Enjoyed taking a science course as a breadth requirement	21	25	.	35	19
16. Think science is a form of creative thought	8	16	22	39	15
17. Understanding of science is essential for engaged citizen	14	47	23	11	5
18. Find it easy to make connections between science courses and other work	10	35	.	49	7
19. Interested in taking more science courses than what is required at Skidmore	25	43	.	20	12

There were statistically significant inter-group differences in response to question 19. female students (as a group) and non-white students (as a group) were more likely to disagree strongly the assertion that they were interested in taking more science courses than what is required.

Appendix E. Curricular models for the cultivation of Science literacy.

1. Stand-alone science literacy course or courses offered by any professor with the competence to teach such a course

2. Traditional 3 or 4 credit offering that fulfills the goals of science literacy and is offered in the context of traditional and ID programs (on the model of NW or CD)

3. 1-2 credit add-on to NR course that compliments the subject being studied and that fulfills the goals of science literacy

    a. offered by scientist teaching NR course

    b. offered by another professor coordinating with scientist teaching NR course

4. 1-2 credit add-on to any NR that does not directly compliment the subject being studied but that pulls on the content of NR courses to understand scientific literacy in general.

5. Collaborative Problem Solving Across Disciplines model (pilot) wherein a group of science and non-science faculty work with a group of students to understand a problem using the methods of science and non-scientific methods.

6. Scientific Literacy in the Major model. Like WIM, each discipline or ID program develops a Scientific Literacy in the Major course or courses and requires students to take it as part of their major program.

7. Organic model: student is advised into courses that help her or him to gain scientific literacy and that fits with her or his personal learning goals and interests. For its part, the college develops an infrastructure of courses that allow students to fulfill these goals and interests and to achieve scientific literacy.

Appendix F

The following expanded list identifies potential areas to foster new science literacy activities at the College, as well as potential strategies to more fully integrate the sciences with the arts, humanities and social sciences (in **bold text**). We position these strategies within four settings: the curriculum, programming, communications and facilities.

A. In the curriculum:
1. Consider various models that address science literacy in either existing courses or through new course experiences:

- ***Collaborative Problem Solving Across Disciplines*** model (Apocalypto pilot regarding Science Literacy, Fall 2012) wherein a group of science and non-science faculty work with a group of students to understand a problem using the methods of scientific and non-scientific methods;

- ***1-2 credit add-on interdisciplinary experience*** such as an intensive winter-term experience (after the Bard-model, http://citizenscience.bard.edu/), or as an intensive weekend program during the semester;

- ***1-2 credit add-on to SR course*** that complements the subject being studied and that fulfills the goals of science literacy (a.) offered by scientist teaching SR course; or (b.) offered by another professor coordinating with scientist teaching SR course;

- *Stand-alone science literacy* course or courses offered by any professor with the competence to teach such a course;

- *Traditional 3 or 4 credit* offering that fulfills the goals of science literacy and is offered in the context of Traditional and ID programs (NW or CD);

- *Create a Science Literacy requirement.* Optimally, this requirement would be created by either replacing or reconfiguring an existing requirement. For its part, the college would develop an infrastructure of courses that would allow students to achieve scientific literacy in courses that may fulfill more than one requirement (double- dipping). For example, a QR or HI course may also fulfill SL requirement.

2. **Establish a timeslot during the week when classes are NOT scheduled to encourage and allow for interdisciplinary projects.** Lack of common meeting times are perhaps the most difficult hurdle to overcome across the disciplines.

B. In programs:
1. **Using existing programs, consider ways to support more interdisciplinary collaboration surrounding science with the idea that this will foster a better appreciation for science literacy.** These might include:

• *an option for faculty teams to collaborate in summer student collaborative research* (e.g. pair of art and chemistry faculty with student[s]);
• *targeting a Tang Mellon seminar to address science* with the hope of developing future exhibitions and interdisciplinary contacts;
• *expanding the offerings of study abroad and internships that focus on science, and pair with regular student forums for presenting these experiences to other students*.

2. **Establish new faculty positions at the intersection of disciplines:**
- *Materials Science and Art Conservation (Chemistry/Tang Museum)*
- *Science Writing (English)*
- *Interactive Design (Art/Computer Science)*
- *History and/or Philosophy of Science (History/Philosophy/Science)*

3. **Establish a regular Science Literacy speaker event** (targeted at drawing a wide attendance). For example: Edward Tufte, *Envisioning Information;* Jonah Lehrer, *Imagine: How Creativity Works*; Daniel Kahneman, *Thinking Fast and Slow;* or Bill McKibben.

<u>C. In communications:</u>
1. **Recognize both students and alums working at the intersections of all the sciences and the arts, humanities and social sciences.** Work with faculty to insure accurate reporting and representation.

2. **Recognize faculty achievements working at the intersections of all the sciences and the arts, humanities and social sciences.**

3. **Work with faculty and communications staff to insure accurate reporting and representation, as well as considering ways to make sharing new projects and achievements easier.**

<u>D. In the facilities:</u>
1. **Develop collaborative research spaces. Make spaces that support adjacencies for science in strategic locations, both in the new science building, as well as in non-science buildings.** For example, in the science building include lab spaces for study of art materials and processes (near chemistry & physics labs), and lab space for study of human evolution and biological anthropology (near biology, exercise science, and geoscience). In non-science buildings look for strategic opportunities to do the inverse (a small lab space at the Tang near collections, small GIS lab near anthropology).

2. **Utilize existing spaces and, if necessary, create new spaces to address the relevance and communication of science literacy.** The Resolution of the Arts and Sciences Exhibition and Lecture Series (Fall 2011) is one example. These spaces or exhibition areas may be either student or faculty run and present artwork, projects, and/or history of science.