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”).

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,

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, 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

Meinwald J. and J.G. Hildebrand. 2010. Introduction. Pp 1-8 in Science and the Educated American: A Core Component of Liberal Education (Meinwald, J and JC Hildebrand, eds). American Academy of Arts and Scientists. Cambridge, MA.

National Research Council, National Committee on Science Education Standards. 1995. National Science Education Standards: observe, interact, change, learn. National Academy Press, Washington, DC.

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 scienc

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 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).

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 tha w302 528.78 cm BT 5ents?

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 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

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

1. Stand-

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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:

- *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.

C. In communications:

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**