

STUDENT EXPECTATIONS, UNIVERSITY GOALS: LOOKING FOR ALIGNMENT  
IN GENERAL EDUCATION SCIENCE

by

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A Dissertation  
Submitted to the  
Graduate Faculty  
of  
George Mason University  
in Partial Fulfillment of  
The Requirements for the Degree  
of  
Doctor of Arts  
Community College Education

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Date: \_\_\_\_\_ Spring Semester 2012  
George Mason University  
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Student Expectations, University Goals: Looking for Alignment in General Education  
Science

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Doctor of Arts at George Mason University

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## DEDICATION

To my parents who taught me to love the natural world, and to my children and grandchildren, in the hopes that they too will love, understand, and care for the world around them and will help preserve it for the generations yet to come.

*“When I consider your heavens, the work of your fingers, the moon and the stars, which you have set in place, what is man that you are mindful of him, the son of man that you care for him? Psalm 8:3-4 (New International Version)*

## ACKNOWLEDGEMENTS

Thanks always to my family, to my son Bob who spent so much of his childhood with a mom immersed in homework, to Jon, Dave, Doug and their families, who must have sometimes wondered about my sanity when I went back to school, and to my husband, Rob, who is always patient, long-suffering, and encouraging.

Particular thanks to Maria Dworzecka, who, when I asked about doing the D.A. program with a concentration in Astronomy, rather than Physics, not only encouraged me, but suggested I might want to teach some astronomy labs. Thanks to Harold Geller for being an excellent mentor and friend, and thanks too to Jessica Rosenberg who helped me think more deeply about science education. And thanks to Mike Summers who opened my eyes to the possibilities of life on other worlds and deepened my appreciation of the life that permeates this one.

Staff and faculty in the Higher Education program made learning so rich and deep that I kept wanting to take more classes, and would have put off completing the degree forever if Nina Joshi hadn't reminded me there are time limits. Thanks to Gail Kettlewell, who gave me such a good start, and helped me see the potential in studying the structure and processes of educational institutions.

Special thanks to faculty and students who gave so generously of their time to share their thoughts about general education science with me. I particularly appreciate the depth of the concern shown by faculty who want their students to get life-long value from their science classes. Thanks to Kim Eby of the Center for Teaching Excellence, a mentor and instigator of change through the curricular innovation grants program, and to Rick Diechhio for guiding the process of formulating new goals and moving the reworking of general education natural science at Mason

Finally, thanks to all those long ago professors at Macalester, most of whom I can no longer name, who made learning exciting, made the sciences real and engaging, and gave me the kind of liberal education that is worth every cent.

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## **ABSTRACT**

### **STUDENT EXPECTATIONS, UNIVERSITY GOALS: LOOKING FOR ALIGNMENT IN GENERAL EDUCATION SCIENCE**

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George Mason University, 2012

Dissertation Director: Dr. Maria Dworzecka

This action research dissertation explores the alignment of university goals, faculty practice, and student expectations for general education natural science courses as a first step to understanding how best to restructure the program to ensure that students are learning in alignment with university stated goals for this aspect of their education. A survey of general education natural science goals checks alignment of goals at George Mason University with goals for similar programs at a range of higher education institutions. Interviews with faculty teaching general education natural science and focus groups with students who have taken required natural science courses yield areas where goals do and do not align and provide perspective on goals and expectations held by those teaching and taking the courses. The results should prove useful to an ongoing effort at the University to evaluate and improve general education natural science.

## CHAPTER ONE – INTRODUCTION

### Personal Statement

*“Man and His World” was basically a course which was to pull together, in a general education pattern, an introduction to humanities, and basic science, and things of this sort, for the non-specialist—sort of the history of science, more than obviously not lab science but history of science, and its relationship to general history and to literature. (Donovan. 2007)”*

Away from home for the first time after a long and lonely train ride from Idaho to Minnesota, I enrolled at a small liberal arts college in St. Paul. When I made the rounds of the tables stationed around the gym for registration, choices seemed limited. All freshmen were required to take “Man and His World” as part of the general education requirements at the time, so I selected a section of that. I was also funneled into a calculus course, a physics course, and a literature course since I would need them eventually to fill requirements for general education. I had applied to the school as a foreign language major and had an advisor in the Spanish department, so I enrolled in German 1 as well.

Physics that semester was a newly developed course on modern physics. It was designed to give students a chance to get in a solid calculus course before tackling classical mechanics and also to whet student interest in cutting edge science. In lab we fired B-Bs at hidden targets and analyzed the pattern the B-Bs made as they bounced off



a Plexiglas shape and marked a strip of red waxed paper we had fastened around the edge of the tub containing the target. We studied tracks of elementary particles through a bubble chamber, measuring curvature of the track to find the mass and charge of the particles, then tried to sort out what interactions we had recorded. In “20<sup>th</sup> Century Literature,” the instructor led us through analysis of *The Great Gatsby*, *Light in August* and *Ulysses*. “Man and His World” was a relatively new course, required for all freshmen, and, incidentally, the most reviled course on campus. Taught in small sections by professors from various disciplines it had at least the semblance of a common curriculum, though the flavor of the course varied considerably. Each professor had a great deal of latitude in texts and approaches, though big themes of philosophy and logic seemed to be present in all section to provide a foundation for our thinking. The readings at times were tedious and I have probably forgotten more than I remember, along with the names and faces of both professors. I do remember reading a book by Ian Barbour about religion and science, and vividly remember a thought experiment involving dropping marbles of various colors into a “black box”, then having to account for why the order in which they came out was different than the order in which they went in. I have referred back frequently to the Barbour book and am quite sure any understanding I have of philosophy came almost by osmosis from “Man and His World.” I wish I could take it again now, I would certainly appreciate it much more than I did at 17.

These general education courses changed my life in ways I could not have imagined. “Man and His World” opened my mind to ideas I had not stumbled across before and have thought about lifelong. In “20<sup>th</sup> Century Novel” my love of reading was

deepened by trying to make sense of Joyce's dense, complex narrative of a single day in Dublin and I was challenged to read a text more slowly by Falkner's subtleties. Today in informal book groups I spot themes, look for ideas and appreciate a book beyond the story because of that one course. Finally, taking "Modern Physics" to satisfy the general education science requirement gave me a vocation. I changed my major and abandoned ideas of a job as U.N. translator in favor of a career as a scientist.

To summarize, these required, but non-major, courses influenced my ways of thinking, introduced me to a career, changed how I approach a favorite pastime, and began helping me develop skills I would need in life. Later I would take courses in religion, speech, political science, and anthropology to meet other requirements and all broadened and deepened my thinking in various ways. Courses in my major helped me develop my understanding of physics and helped me develop needed skills, while the rest of the courses developed the heart of my scholarship and shaped my attitudes toward the world. I am glad these general education requirements were part of my undergraduate education.

What was in the minds of the those who developed "Man and His World" and decided what requirements should be part of the common education for graduates? Macalester chemistry professor Truman Schwartz taught a section of the course and reported in an interview "the syllabus included philosophy and literature and a little religion and lots of stuff I was interested in but didn't know much about. I learned as much as the students--probably more" (Schwartz, 2007). I haven't uncovered reports from those who shaped the general education curriculum, but I am grateful to whoever

they were. I am convinced that, even if I had not changed my major, I would still be intrigued by cosmic rays and how the natural world works because of taking both “Man and His World” and “Modern Physics.” General education was transformative for me and I’m sure for others, perhaps in ways that the designers of the program had hoped.

One of the reasons I wanted to pursue the following study of general education science at George Mason University, was to see if what was valuable to me personally in a small Midwestern school in the 1960s might also be alive and well in general education science in the context of a large state university in the 2010s. What I found, and what might be done to help make general education science a more vital and transformative part of the general education curriculum are the focus of this study.

## **Background and Context**

Ask my students in Astronomy 111 why they are taking the course and the answer will probably be along the lines of “I have to take science and I already took Biology in high school” or “I have to fill the science requirement.” Faculty members who teach the courses may answer “students need science to be good citizens,” or perhaps “it’s important to produce citizens who will support funding for science,” or simply “Because it’s required” (Shoenberg, 2000). From either point of view, science is treated as a kind of mental medicine - necessary for intellectual health but not particularly palatable to the average student. Anecdotal evidence suggests that many students fail to see purpose in taking science at the college level and put minimal effort into the courses, attempting to “get them out of the way” as painlessly as possible (Keen, Mitchell, & Wilson, 2008; Keller, 2002; Leskes & Wright, 2005; Voparil, 2008). Although science is nearly always

one of the subject areas included in general education (Bourke, Bray & Horton, 2009) and is one of the core learning areas addressed by state and accrediting agencies when they evaluate undergraduate education (AAC&U, Liberal education outcomes, 2005), it is not clear what aspects of science matter most for non-science undergraduates. Students at Mason, like those at many universities, choose from a broad menu of courses with varying subject matter and epistemology. It can be difficult to find commonalities when the content, laboratory techniques, and measurement methods for the various science disciplines are all so different. Standard assessments using multiple choice questions seems to be based on the assumption that there is something fundamentally the same in all science courses that can be taught and measured. The web page for George Mason University says of the natural science requirement, “Courses in this category are intended to provide students with an understanding of natural science. The critical approach of the scientific method, the relation of theory and experiment, the use of quantitative and qualitative information, and the development and elaboration of major ideas in science are addressed.” (George Mason University Provost’s office, General Education Requirements, 2010). If familiarity with the processes of science and ability to think critically through scientific reasoning are valuable for college-educated citizens, then it seems important that students understand the purpose of taking general education science, are motivated to put in the necessary effort, and are taught in ways that help them achieve the outcomes the courses are tasked to support. Finally, it will be important to close the loop through assessing gains or abilities in the targeted areas.

Assessing what students learn at the institutional level is tightly linked to goals for required courses both within the major and in general education portions of the curriculum. George Mason University (Mason) is required to assess a number of competencies including scientific reasoning (George Mason University Office of Institutional Assessment, 2011). Increasingly, assessment is valued at the institutional level for its role in improvement and reform of current programs (Leskes & Wright, 2005). For non-science majors, students are expected to acquire scientific reasoning skills primarily from the general education science they take, usually in the freshman and sophomore years. Mason has gone through several iterations of developing an assessment for general education science, but has not come up with an assessment tool that effectively measures the scientific reasoning skills expected of students completing general education science. The most recent test was developed by a group of faculty who teach courses that fill the general education natural science requirement. The assessment was structured to look for improvement in learning related to the scientific reasoning goals, which in turn were based on general education goals for natural science. The value-added assessment found no significant change in reasoning abilities as measured by the test. I will discuss this assessment in more detail in the section on research design, but an important question the raises is whether learning goals defined by the University for natural science are adequately addressed in the natural science courses that fill the requirement. If they are not being addressed there could be multiple reasons. Instructors might be unaware of the general education goals of the courses and may not have a clear idea of what the students taking them already know from high school (Shoenberg, 2005).

In fact, it is the question of whether university goals, faculty implementation and student achievement of the goals are aligned that provided the impetus for the work in this dissertation. The question came into sharp focus in Spring 2011 when the College of Science began plans to revise the curriculum for general education science and opened the door to changes in goals, in teaching methods and content of the curriculum.

### **Research Questions**

As a reminder, the fundamental problem that is driving both the research reported here and the on-going revision of general education science at George Mason University, is the problem of whether goals that the University states for general education science are being reliably transmitted and understood by students whose only college experience of science comes from 7 or 8 credits of introductory laboratory science. Since students can select from a menu of courses in many different science disciplines, and since each of the disciplines has different approaches to doing science as well as different content, it seems likely that transmission of goals is uneven at best. Even if goals are communicated reliably to instructors, do they drive instruction in a meaningful way? Do students benefit as intended? And, an even more fundamental question is whether the structure of general education science at Mason will support on-going change in science classes as goals are restated or changed?

The foundational question for this project is:

If a consistent underlying structure could be formulated and implemented in general education science courses, with course content built on the structure but remaining flexible and dynamic, would goals be transmitted from institution to instructors and through courses to students ?

My research questions for this study address the question of current transmission of goals and are as follows:

- How do goals for general education science at Mason align with general education science goals at other institutions?
- How do university goals for general education natural science reach the instructors charged with implementation of the goals in courses?
- How do the instructors incorporate Mason goals in their courses?
- Are goals for general education science communicated to students and if so, how?
- What do students, and instructors see as the desired long term outcomes of studying science for students who are not majors?

## **Research Design**

**Action science.** The research design for this study is action science (Argyris, Putnam, & Smith, 1985). More specifically, the methodology I have chosen can be categorized as a problem-based methodology under the action science heading, a research method dedicated to improving practice (Robinson, 1993). In this case, the method is being applied in the educational setting of a large state university where I am involved as both researcher and participant in the process of evaluating and restructuring general education science.

In problem-based action science, the researcher can be an insider to the process of identifying analyzing and addressing a particular problem (Herr and Anderson, 2005, p. 14; Shavelson and Towne, eds. 2002). That is, the researcher may be collecting data, while using the data collected to work collaboratively within an organization to effect change. This “insider” research may be one of the inputs in the change process, and the process may influence the research.

In the case of alignment of general education goals and practice at Mason, I have been involved for the last five years as part of the committee developing an assessment for general education science and am currently working with a group within the College of Science to restructure the general education science curriculum. I have taught general education science at Mason and at Northern Virginia Community College over the last two decades and have been concerned about how much of value students get from the courses. The question of what non-science majors may gain by studying science has been a driving force in my return to graduate school and pursuit of the D.A. degree in the Higher Education department at George Mason University. Because of my involvement as instructor, and course developer of general education science courses, this study fits well under the general heading of action science. In particular, what I have learned through gathering information about goals and processes of general education at other institutions and from interviews and focus groups at Mason has informed how I participate in the change process at the institution. The fact that I am an insider to the process, not a detached observer does raise questions of bias that I will deal with in the Methodology section.

**Stages of the investigation.** My contribution to the general education reform process is a case study to investigate issues of alignment of general education at Mason. This investigation has three major stages. First, I will examine how science is treated in general education programs at a small sample of higher education institutions by examining goal statements, locus of authority for general education science courses (department, general education program, university core program or somewhere else) and



types of courses that meet the requirement. Second, I will do a kind of “core sample” at George Mason University to compare perceptions of the program at the levels of students, faculty, and administration as represented by institutional goals and requirements at Mason. Finally, I will explore potential directions of Mason as the school reviews and revises the program here.

In the Methodology chapter, I will give an overview of general principles of problem-based methodology and then a synopsis of the specific methods employed in this study.

### **Definition of Terms**

**Scientific literacy.** A frequently cited goal of general education is to help undergraduates become scientifically literate. There is not much agreement on what scientific literacy means, however. Coming up with a precise definition is problematic, but it is instructive to look at the ways the phrase can be interpreted to understand the different images it conjures up for different advocates.

First, scientific literacy can mean familiarity with “great ideas” in a variety of science disciplines (Trefil, 2008, Trefil & Hazen, 2010). In this view, students learn the basic concepts and some of the history underlying the major sciences - Chemistry, Biology, Physics, Geology, etc. - in order to have a starting point for understanding current events in science and for making decisions about science questions in the public square.

A second view of scientific literacy would involve using concepts, skills and values of science in everyday decisions. (DeBoer, 2000).

Third, those concerned with higher level thinking skills and intellectual habits of mind that develop as students participate in problem solving in a science course and that have value in the world beyond the lab, define these as the bottom line indicators of scientific literacy. Referred to as scientific attitude (Dewey, 1930) this view of scientific literacy incorporates such things as open mindedness, willingness to change opinions in the light of new evidence, and understanding of theory as contrasted with fact. A course designed to develop this kind of literacy might include a problem-based learning approach to a science question with relevant science principles introduced as necessary. Such a course might also include helping students evaluate science critically to sort sound science from pseudo-science and invalid science claims.

Fourth, an emerging view of science literacy in light of the current surge of interest in “crowd-sourced” science, as exemplified in Operation Budburst or the Zooniverse is that of science as a collective, not individual activity (Roth & Lee, 2002). Each participant in a local environmental initiative, for example, brings skills and knowledge to the group enabling relatively untrained individuals to participate in science in real time. The kind of background understanding, or scientific literacy, required for a person to participate in these efforts may be significantly different from what would be necessary for individual decision-making.

DeBoer (2000) lists these nine possibilities for framing scientific literacy which I have paraphrased as:

- Science as a cultural force
- Science as preparation for work in a technology dominated world
- Direct application of science to everyday life

- Informed citizen
- Way of examining the natural world
- Ability to understand science reports in popular media
- Science as a source of aesthetic enjoyment
- Preparation for citizens sympathetic to science
- Ability to understand relationship of technology and science and their importance

In the face of such a long and varied list, DeBoer (2000) concludes that scientific literacy is necessarily a broad concept and that those who want to set standards will need to make choices that will vary from place to place, and, one might add, time to time as perceptions of need for science understanding and its value to society change. A working definition of scientific literacy at Mason will come from the process of defining goals and may include elements of many of the above formulations. While I will explore the concept of scientific literacy in more detail in chapter 2, what is meant by the term will have a strong dependence on context, particularly in interview and focus group data reported in the Results section and in the process of defining goals in the general education science reform effort at Mason.

**Scientific reasoning assessment.** While scientific literacy is a broad and slippery concept to define, pinning it down in order to measure it can introduce the opposite problem. Narrowly constructed assessments measure elements of a narrowly defined curriculum. Tests of scientific literacy (or as it is labeled at Mason, scientific reasoning) may include primarily factual knowledge that the test developers considered to be a necessary part of the science cannon if developers hold to the idea of science as a body of facts held in common by college graduates. However, not everyone who has

taken one or two general education science course as an undergraduate will necessarily know facts from a broad range of science disciplines. Even when tests measure general science process skills, as might be advocated by proponents of the science attitude definition of scientific literacy, it is hard to find common ground. For example, students taking introductory physics courses may spend a large part of their time solving problems and doing quantitative analysis of lab results. Students in biology, on the other hand, may do very little problem solving in the introductory courses, but spent time instead in identification and classification skills. Student expectations and epistemologies vary depending on the science discipline (Lising & Elby, 2005). A “one-size fits all” assessment is not likely to show significant results in this case either. Even when scientific literacy is carefully defined it will surely prove difficult to assess. It will be critical for programs not only to define scientific literacy in the context of the particular school and time, but to develop assessments that take into account the varied experience of students with formal and informal science.

For purposes of this report, I will refer to the definition of scientific literacy used by Mason to outline competency in this area up to spring of 2011. It is likely that the definition will change as the goals and structure of general education science change in the next months and years and that assessment of scientific reasoning will be based on new criteria. Scientific reasoning goals current at the time of writing are included in the appendices.

## **Significance of the Study**

Concern that the United States is falling behind in science education has been a common theme at least since the launch of Sputnik in 1957 (AAC&U, 2010, National Commission on Excellence in Education, 1983). Over the last few decades businesses, and nation science advocacy organizations and political leaders have all called for efforts to increase STEM learning for students at all levels. However, efforts to increase learning may fall apart if goals and standards are not clear and not effectively assessed. The AAC&U in its 2007 report , *College Learning for the New Global Century*, notes that it is foundational to give a clear answer to “what do students need to know?” if college is not to be a set of requirements to check off a to-do list. According to the report, establishing goals and ensuring that there is good alignment with practice by developing appropriate assessments is a vital part of educating and graduating effective citizens.

Two major efforts underway at Mason could benefit from findings of this study about alignment of goals and practice. First, the Office of Institutional Assessment continues to work to create an assessment for scientific reasoning that aligns with the goals of the general education natural science program. The second effort is a move to redesign the curriculum for general education science at Mason. In both cases, issues of alignment are important. With classes originating in departments that use different science epistemology and pedagogy it may always be a challenge to define and measure common outcomes for students who select one or another of the offerings. Institutions with programs similar to Mason’s, may face similar questions of alignment and may

benefit from some elements of this case study. More detail about the two efforts at Mason that inform and may benefit from this study follow.

**Mason scientific reasoning assessment.** In the early 2000s the faculty scientific reasoning committee at Mason designed assessments to determine if students were developing scientific reasoning skills in their general education science courses. Faculty who teach general education science courses cooperated to develop an assessment of scientific reasoning to be administered to students at the beginning and end of their program of required general education science courses. The group found it difficult to define scientific reasoning goals that all the disciplines providing general education science courses shared, but eventually come up with a multiple choice assessment with questions that seemed to test reasoning rather than specific content. The assessment was administered to a large group of students as a pre-test, then again at the end of the semester as a value-added assessment. The results were disappointing; there was no clear pattern of improvement (George Mason University Office of Institutional Assessment, Scientific Reasoning page, 2010). One reason for that could have been that students took the pre-test more seriously than the post-test. Another could be that the assessment did not measure what was being taught in the courses - an issue of misalignment of goals, practice and assessment. Or, it could be that scientific reasoning develops over a long period of time, and that changes over one semester were not measurable. Since then the process of evaluating general education has been overhauled. A four step process is being developed to assess outcomes as follows:

1. **Defining Common Learning Outcomes:** for each general education category, there should be a set of common learning outcomes across all courses

regardless of the discipline. The assessment focuses on two questions: to what extent faculty address these learning outcomes in their courses and how well students achieve these outcomes.

2. **Assessing Learning Outcomes and Collecting Data:** all assessment will be embedded in the course. Faculty members or course coordinators will provide evidence of course content and pedagogy, and collect and submit samples of student work, in a process detailed later in this guide.

3. **Analyzing and Reviewing Assessment Data:** faculty teams develop review criteria and standards and conduct the review; the Office of Institutional Assessment provides assistance with data analysis. The results are shared with the General Education Committee and the faculty who participate in the assessment. The aggregated results are reported to the State Council of Higher Education for Virginia (if required) and are for the SACS re-affirmation of accreditation. No individual faculty results are made public.

4. **Implementing Curricular Improvement:** the ultimate goal for the general education assessment is to use data to identify the strengths and weakness of the program and plan for curricular improvement. For example, faculty may discover ways to modify existing course content, tests or assignments to better align the outcomes of the tests/assignments with the common learning outcomes for the category. (George Mason University Office of Institutional Assessment, General education page, 2011)

This study fits in primarily as the first step of defining common outcomes and inquiring about the level at which the outcomes are embedded in courses. Unless institutional goals and objectives are embedded in courses and their purpose understood by faculty and then conveyed to students it seems unlikely that learning objectives can be assessed meaningfully. However, if common learning goals can be selected that fit easily within the course offerings across science disciplines, the way to a valid assessment of scientific reasoning should become clearer.

**Mason general education science restructuring.** Concurrent with this research project and writing up results I have been part of ongoing small group working on potential changes to general education science at George Mason University. Representatives of institutional assessment and the provost's office organized two

introductory workshops in January, 2011. Those who attended the first two meetings were invited to continue discussing plans to reform the general education science curriculum. I will provide an afterward to report on the progress of the curriculum reform group as it stands now. Actions of this group are relevant to this study because I have had some input to the process because of insights gained from the interviews and focus groups on-going during the process. In addition, the group process has helped me focus my thinking about what is important to address in the curriculum and has also helped me understand areas where faculty are reluctant to change, or enthusiastic promoters of change. Whether my research study will have an impact on the change process is yet to be seen, but changes that resolve some of the problems of alignment would provide validity for the action science process reported here.



## CHAPTER 2: THEORETICAL FRAMEWORK AND LITERATURE REVIEW

*“If education is life, all life, has, from the outset, a scientific aspect, an aspect of art and culture, and an aspect of communication. It cannot, therefore, be true that the proper studies for one grade are mere reading and writing, and that at a later grade, reading, or literature, or science, may be introduced. The progress is not in the succession of studies, but in the development of new attitudes toward, and new interests in, experience.” (Dewey, 1964, p. 434)*

### **Introduction**

Requiring students to take courses that are not part of the major as part of an effort to ensure a common base of learning has a long history in American higher education (Bok, 2007; Levine, 2007; Reuben, 1996). In the following sections, I outline some of the historical purposes and goals offered as reasons for including a program of general or liberal studies in education. I also show when science as a discipline entered the ranks of required courses in the general education part of the curriculum. The four main sections of this literature review will move from theoretical underpinnings of this study, through history of general education science, contemporary understanding of the role of science in undergraduate education, and finally, to an overview of general education science and its ongoing reform at George Mason University.

### **Theoretical Framework**

The motivation behind the work involved in this dissertation comes from my involvement with general education science, first as a student, later as a teacher, and finally, as a faculty member involved in assessment and reform efforts. As a faculty

member teaching physics at a community college in the 1990s, I wondered what students were getting in the long term from taking physics courses. Too many seemed to be taking it only because they had to, and getting little from it. I had no idea how to do it better, or how to encourage students when I was not sure myself what use the course would be to them after they finished college. The question has stayed with me as I have continued my own studies, and I hope through this writing and involvement in reform and assessment at George Mason University to suggest some answers in order to improve the general education science experience as we move forward. The heart of the theoretical framework that follows comes from the ideas and educational philosophy of John Dewey and those who carried his ideas into the present.

**John Dewey's educational philosophy.** One of the most influential American philosophers of education is John Dewey (Smith, M., 1949; Kilpatrick, 1951; Levine, 2006). His philosophy of pragmatism, and his positioning of education in community rather than exclusively in the mind of the individual, make his ideas foundational to examining the role of education in a democratic society. His pedagogic creed (Dewey, 1964, pp.427 - 439), emphasizes the importance of school as a social institution and of education as preparation for life in the broader community. (Levine, 2006) The ideas Dewey explores in many of his writings that are most relevant to this study are:

- Experiential Education – learning is grounded in student prior experience and understanding (Dewey, 1964, Dewey, 1933)
- Attitude of inquiry - the process of inquiry in science is foundational for education in all subjects (Dewey, 1933; Dewey, 1938)

- Goal based education- the importance of formulating goals which are not fixed endpoints, but aims, the places where turning points occur. (Dewey, J., 1964, pp. 70-80)
- Science and democracy are linked – both within the classroom and in the broader society. Science allows humans to control and regulate experience. (Dewey, *Democratic Education*, 1944, referenced in Deneen, 2003, p.1)

With this framework in mind, I have examined general education science at George Mason University, hoping to understand its place in the undergraduate curriculum. Through the process of action science research, also influenced by Dewey's philosophy, I hope to help to redefine and position it to meet the needs of citizens in a democratic society.

I will explore each of these ideas in more detail here, then return to them as I look at goals for science education and the methodology of action research used in this investigation.

*Experiential education.* Dewey believed education must start with the individual's psychological and social state rather than with a superimposed external plan which he felt might or might not connect in useful ways with the learner. (Dewey, 1964, p. 427-429). Dewey notes that, to use experience as a starting point for education is not to make ideas less, but rather more, as they provide a starting point for experiment and exploration rather than a fixed end. (1964, p. 384). This accords with current learner centered practice based on research about how people learn (Bransford, Brown & Cocking, 2000). A constructivist approach takes into account that it is in everyday experiences that learning begins. The job of education is to make sense of a continually broadening set of life experiences (Dewey, 1964, p.386).

Dewey makes it clear that the type of education he advocates is not chaotic, but structured in a way that allows people to enter an experience at various levels of prior understanding. While he advocated in some cases beginning with activities like weaving or cooking, it was not in order to learn those things and stop, but to have a starting point of common experience on which to build. In terms of structuring educational experiences he describes a good project as "...sufficiently full and complex to demand a variety of responses from different children and permit each to go at it and make his contribution in a way which is characteristic of himself." (Dewey, 1964, p. 177).

In addition, Dewey states that a good project should "...have a sufficiently long time-span so that a series of endeavors and explorations are involved in it, and included in such a way that each step opens up a new field, raises new questions, arouses a demand for further knowledge, and suggests what to do next on the basis of what has been accomplished and the knowledge thereby gained." (Dewey, 1964, p. 178).

Regarding the role of science in general education, Dewey plays an important role as a proponent of experiential hands-on learning. In Dewey's view, students must engage actively with the world in order to understand it. This means beginning with what is familiar. (Dewey, 1933, p. 224). On the teaching of science he says:

"...one of the greatest difficulties in the present teaching of science is that the material is presented in purely objective form, or is treated as a new peculiar kind of experience which the child can add to that which he has already had. In reality, science is of value because it gives the ability to interpret and control the experience already had. It should be introduced, not as so much new subject-matter, but as showing the factors already involved in previous experience and as furnishing tools by which that experience can be more easily and effectively regulated" (Dewey, 1933, p. 434).

Thinking experimentally involves approaching ideas with a critical attitude and applying investigative skills and thought processes to the problems they present (Levine, 2006). While students do not come to science able to do this immediately, Dewey outlines the stages educators can guide them through as they make connections between the material world and the theoretical world of science. Dewey's three stages illustrate how students move from concrete to abstract:

1. Begin with what is familiar and connect new topics and principles through activity when possible. This should not involve using objects for the object's sake, but rather using the familiar in context.
2. Transfer interest to intellectual matters. For example, in Dewey's view carpentering or shop working can be a lead-in to geometric and mechanical problems. Cooking is a starting point for chemistry and physiology. Making pictures leads to study of perspective, pigments, and brush techniques.
3. The final stage is the abstract, taking delight in thinking for the sake of thinking. This has an aspect of reflection and self-directed pursuit of ideas (Dewey, 1933, pp. 225, 226).

Moving science education from the concrete to abstract realm is most likely to happen in laboratory instruction where lab exercises could be designed to move from an initial question to hypothesis testing, experimenting, and evaluation of data collected, then to deeper thinking about theory. Thought experiments and problem-solving, when problems are loosely structured, consistent with Dewey's approach, lend themselves to seminar, recitation, or even carefully structured lecture settings.

*Education rooted in scientific ways of thought.* For scientists this has perhaps been one of the most controversial of Dewey's thoughts. In *How We Think*, Dewey listed five steps in thinking: "(i) a felt difficulty; (ii) its location and definition; (iii) suggestion of possible solution; (iv) development by reasoning of the bearing of the

suggestion; (v) [and] further observation and experiment leading to its acceptance or rejection.” (as cited in Rudolph, J., 2005a, p. 366). The problem for scientists is that the idea of thinking as method, and its connection in Dewey’s work to science as a foundational thought process for education, led to a simplification of his ideas into a series of steps to follow in both the educational process and in experimental science. Working scientists found it incredible that the complex process of doing science could be reduced to a simple set of steps. (Rudolph, J., 2002). It is important to understand that Dewey had used thought processes he saw in scientific thought, abstracted them to use more generally, and did not claim that they represented steps in doing science. (Rudolph, J., 2005a).

It is important here as well to remember that in including Dewey’s approach to thinking as emulating scientific thought, I do not intend to advocate teaching a rote series of steps labeled scientific method to general education science students, but rather to explore using science thinking as a way to help establish logical thinking patterns that will be useful in areas beyond the required science courses. In Dewey’s words “*The function of reflective thought is, therefore, to transform a situation in which there is experienced obscurity, doubt, conflict, disturbance of some sort, into a situation that is clear, coherent, settled, harmonious.*” (emphasis Dewey’s from *How We Think*, 1933, p. 100-101). In a similar vein, a prime value in science is curiosity, which leads to another important idea found in Dewey’s thinking, the attitude of inquiry.

*Value of an attitude of inquiry.* Dewey presents two possible ways to approach science, the classical view of learning by “fixed authority” and “...systematic utilization

of scientific method as the pattern and ideal of intelligent exploration and exploitation of the potentialities inherent in experience.”(1964 , p. 384). He gives an example of a traveler at a crossroads who must either take one road or the other and trust in chance, or use inquiry to find evidence to make an informed choice. (Dewey, 1933, pp. 13, 14).

When Dewey speaks of using the methods of science he is not referring to the kind of cook-book formula often presented in textbooks as the scientific method. Rather, he advocates methods of science in the sense of developing a critical or inquiring attitude to test beliefs and assumptions. (1933, p. 386). His view of this process is rigorous in that apparent correlations between otherwise isolated events must be tested intelligently.

It is not hard to untested or unsupported beliefs that have consequences for action on the part of individuals and decision-making bodies. Such ideas are rife when it comes to explaining human behavior – “Students are disengaged because they don’t care about science,” or “Free health care leads to overuse of the medical system.” Examples of such thinking also occur when explaining patterns in nature; “Warming trends are followed by ice ages, so we can expect a cooler, not warmer climate.” “Vaccinations cause autism,” and so on. This aspect of Dewey’s philosophy comes into play when discussing goals of general education science.

*Goals based education.* Dewey’s views support the idea of lifelong education, though he saw much of real education occurring outside formal settings. Dewey said the aim of education is to “...to enable individuals to continue their education -- or that the object and reward of learning is continued capacity for growth” (*Democracy and education*, 1916, p. 119).

Dewey makes connections between what we value as the goals and endpoints of education and how educators can teach with such goals in mind. In his use of the word “aims” it becomes clear that goals are more like direction markers than stopping points. Educational goals which are imposed from outside and become ends in themselves are not what Dewey is talking about when he refers to goals. Instead, he sees the progress and stages of education as having intrinsic value. Goals set a direction, but the journey is key. In Dewey’s words:

“To see the outcome is to know in what direction the present experience is moving, provided it move normally and soundly. The far-away point, which is of no significance to us simply as far away, becomes of huge importance the moment we take it as defining a present direction of movement. Taken in this way it is no remote and distant result to be achieved, but a guiding method in dealing with the present. The systematized and defined experience of the adult mind, in other words, is of value to us in interpreting the child's life as it immediately shows itself, and in passing on to guidance or direction.” (Dewey, 1902, p. 18).

Dewey sees the purpose of education as social. (1964, p. 16). He warns against a split between “knowledge and action, theory and practice” which he considers harmful to both education and society (1964, p. 19).

An echo of this is found in C.P. Snow’s idea of two separated cultures of science and literature which must be brought together in order to produce effective action in the wider world. (Snow, 1969). Snow saw a culture of technology with limited power to transform due to lack of political connection, and a literary culture belonging to those with political power but no understanding of science and technology. He believed the



split between the two prevented technological advances from reaching world populations in desperate need (1969).

A fitting goal following from Snow's *Two Cultures* analysis would be education that ensures a minimum understanding of both science and the great cultural works, then teaches students to use strengths of both to tackle world problems. The education is not an end in itself, but a necessary aim along the way to social betterment.

Dewey warns "Every divorce of end from means diminishes by that much the significance of the activity and tends to reduce it to a drudgery from which one would escape if he could" (*Democracy and education*, 1902, p.124). This doesn't preclude structure and standards, but again foreshadows the current research about motivation as a prime factor in effective learning (Bransford, Brown & Cocking, 2000; Pintrich, 2003).

In Dewey's philosophy, thinking can be either concrete or abstract, depending on purpose. Thinking is complete when used, though the use can be individual or communal. Whether concrete or abstract, thinking itself is not an end, as Dewey explains:

*When thinking is used as a means to some end, good, or value beyond itself, it is concrete; when it is employed simply as a means to more thinking, it is abstract.* To a theorist an idea is adequate and self-contained just because it engages and rewards thought; to a medical practitioner, an engineer, an artist, a merchant, a politician, it is complete only when employed in the furthering of some interest in life – health, wealth, beauty, goodness, success, or what you will (Dewey, 1933, p. 223).

A difficulty is deciding on appropriate goals for non-science majors who are not planning to put what they learn in science into practice of science, and how far to attempt to move students along the road to abstract thought. It may be that the main good for

general education students taking science will be a personal good, seeing beauty, or pattern in the natural world, or developing an idea of the place of humans within the natural world. On the other hand, a broader goal that may be appropriate for this group connects to a primary goal of public education in the U.S., that is, science education to support the ideals of a democratic society.

*Link between science and democracy.* Dewey argues that the fact that citizens both elect, and are subject to those they elect, is a superficial reason for valuing education. The deeper importance of education in a democratic society is that democracy rests on shared experience, on the breaking down of class, race, and territorial barriers. Education must be available to all to avoid lapsing into a stratified system of class or privilege. In his words:

A society which makes provision for participation in its good of all its members on equal terms and which secures flexible readjustment of its institutions through interaction of the different forms of associated life is in so far democratic. Such a society must have a type of education which gives individuals a personal interest in social relationships and control, and the habits of mind which secure social changes without introducing disorder (Dewey, 1916, *Democracy and education*, p. 115).

Science has a double role here, both as a subject of study and a source of method of approach to problems in general. Science and democracy are both "...animated by a spirit of investigation, constant reconsideration and revision, and a practical orientation toward solving discrete problems." (Deneen, 2003).

It is in the idea of making a contribution that the student's role as a member of a democratic society comes into play. In formal education, the teacher selects influences and helps the learner respond to these influences, then tests as a way to measure

“fitness for social life” (Dewey, 1897) as well as to guide the student to ways where the person can contribute most.

Science enters the picture in its function as a way of tackling problems of all sorts, not only in science. Dewey, along with educators Charles Eliot and Arthur Hadley, linked effective citizenship to what they saw as values embodied in science: curiosity, critical thinking, and freedom from prejudice. (Reuben, 1996, p. 136).

The link here between science and democracy is that science gives a way of thinking and speaking about the world with a sound basis of interpretation and understanding. This idea has been extended and expanded by current educational thinkers to include the idea of empowerment. (hooks, 2010; Freire, 2000).

**Dewey’s ideas extended.** John Dewey’s influence extends to the present, perhaps especially in his association of the need for education in a democratic society, and empowerment of its citizens (hooks, 2010). but also in the ideas and ideals of pragmatism as applied in the liberal arts (Churchley, 2011; Swan, 2011), as well as in the very idea of action science (Argyris, et. al. , 1985). I will discuss action science in Chapter 3 on Methodology. A brief discussion of empowerment and a close relative of pragmatism, constructivism, (Gordon, 2009; Dabbagh, 2002-2006) follows.

*Empowerment.* Citizens who understand basic concepts and terminology of science are more likely to have a voice in scientific matters than those who don’t, even if they do not go on to careers in science. Empowerment comes from education (hooks, 2010; Freire, 2000). The kind of education necessary for empowerment is not dispensed knowledge that is given from outside to fill student’s minds, rather, education that

empowers confronts students with problems that they must solve (Freire, 2000, p. 76). As Freire puts it, “The students – no longer docile listeners - are now critical co-investigators in dialogue with the teacher” (Freire, 2000, p. 81). This resonates with Dewey’s philosophy on many levels. Education is culturally situated (Dewey, 1987/1964, pp. 427, 429, 432), is scientific in that the scientific approach to problems can be applied in other life situations, (Dewey, 1928/1964, p. 169 - 181) and it has a purpose that extends beyond the individual to the community. (Dewey, 1908/1964, p. 427 – 439, esp. p. 437-439). Mason’s own general education rationale (See Appendix A) does not use the word empowerment, but the idea is there in the goal of enhancing liberty as students move through the general education program. To be educated is to have a right to make opinions known as well as to be able to evaluate opinions and statements based on evidence. While one or two courses in a science discipline cannot make a student expert in a science field, practice with evidence based thinking through science coursework, combined with the confidence and knowledge to read science documents independently, theoretically would result in a graduate confident and capable of self-educating to make informed decisions on science issues (George Mason University Provost’s Office, 2011; Trefil, 2008). Stem-cell research and global warming are two contemporary examples that, while not trivial, can be understood in broad outline by anyone willing to do some background reading and evaluate evidence based on conventions in science.

Again, Dewey's view of science method as foundation for all kinds of problem solving implies that training in scientific problem solving should have applications to problem solving in general.

*Constructivism.* The current constructivist educational theory and brain based research as exemplified by the National Academies *How we think* (Bransford, Brown & Cocking, 2000) give new authority to Dewey's thinking about problem solving and scientific thinking. Examples of contemporary educational strategies that have the potential for empowerment through science courses for non-majors are peer instruction (Green, 2003; Mazur, 1997, Rosenberg, Lorenzo and Mazur, 2006), problem-based learning, and just-in-time teaching (Novak, Patterson, Gavrín and Christian, 1999), and a variety of other learner centered pedagogies in the sciences (Gordon, 2009; McDermott, 1996; Redish, 2003; Slater and Adams, 1999, University of Maryland Physics Education Group, 1997), all of which involve students in the process of posing questions and working toward solutions with available content knowledge and concepts

### **Brief History of General Education in the United States.**

General education in some form has been an area of great interest and some conflict over most of the history of higher education in the United States. In its colonial beginnings, higher education functioned as a training ground for ethics and character. Based on a common curriculum centered on classical subjects, it aimed at producing community leaders and educated elite (Robson, 1983). In the fixed set of topics, physics, the study of the whole created realm, animate and inanimate, was the science component of the "encyclopedia" or circle of arts (Reuben, p. 17).

Experimental science came into the picture much later during the transition to the German research model of the university in the mid- 1800s. At that point, with the institution of the PhD, and majors, educational models began to emerge that valued both breadth and depth of learning (Bok, 2006, pp. 13-17).

Through the 20<sup>th</sup> century, a strong undercurrent of understanding that a college degree should include more than just vocational training helped sustain both the major and a core curriculum (Aikenhead, 2006; DeBoer, 2000). While the nature of the common curriculum has taken a variety of forms over the last 150 years, and seems always to have been somewhat under threat from expanding demands of the major, some version still exists in most institutions today (Hart Research Associates, 2009).

The next sections examine how, through all the changes on the road to the current higher education structure in the U.S., the ideal of a well-rounded, well-prepared citizen has shaped the curriculum, broadening the experience for undergraduates.

**Early general education models.** When America's great universities, Yale, Columbia and Harvard among others, were founded, education was classical, with a primary goal of developing mental disciplines through translating texts, debating and solving math problems. Few attended college and those who did were educated to practice mental discipline, ethics, and civic responsibility (Bok, 2006, p. 12-13; Reuben, 1996, p. 22; Rudolph, F., 1990, p. 6). During the early 1800's, when college doors began to open to a larger, and more diverse portion of the population, and the number of topics considered necessary was growing at a rapid pace (Reuben, 1996), a spirit of egalitarianism in the U. S. led, eventually, to abandoning most formal educational

requirements (Rudolph, F., 1990, Chapter 14). Rather than following a set curriculum, students went to school primarily to prepare for a profession. Students were free to select a set of courses based on their own interests but there was often little coherence or direction (Kerr, 2001).

Yale College in 1828 rejected the idea that education needed to conform to business practices and focus on practical preparation (Kirp, 2003, p. 256). Rather, as the Yale Report of 1828 put it, the purpose of a college education is to “form the taste and discipline the mind” (Yale Report of 1928 as cited in Kirp, 2003, Yale College, 1928).

By the mid-1800s American universities had evolved considerably and the idea of developing a common, unifying curriculum was beginning to take hold. The idea of a broad curriculum to produce well-rounded graduates had never completely disappeared. A number of leaders in higher education at that time probably shared the vision of Cardinal Newman, founder of the University of Dublin who said the university:

“...aims at raising the intellectual tone of society, at cultivating the public mind, at purifying the national taste, at supplying true principles to popular enthusiasm and fixed aims to popular aspirations, at giving enlargement and sobriety to the ideas of the age, at facilitating the exercise of political powers, and refining the intercourse of private life.” (as cited in Kerr, 2001, p. 2).

The purposes of university education as outlined by Cardinal Newman resonate with modern goals of liberal education as formulated by national advocacy groups such as the AAC&U who list both public and private aims for general education programs (Liberal Education Outcomes, 2005).

The rise of research universities on the German model exacerbated the problem of what a common base of learning should be as the focus of college education shifted to majors and electives.

Departments replaced loose collections of courses and students began to specialize to prepare for professions during this period (Kerr, 20001, p. 4). At the same time, the number of courses exploded and universities got larger and larger. A key question in the period became whether it was advisable to rigidly structure what students learn, or better to allow a wide range of individual choice (Rudolph, F., 1990, Chapter 14). As Kerr (2001, p. 11) puts it, “...the professor’s love of specialization has become the student’s hate of fragmentation.” While opening up higher education to an elective system had allowed professors to teach their specialties and the university to develop research programs (Levine, 2006, p.22), the focus has shifted away from establishing a common ground of learning for all who graduated from college. The fear that college could become simply vocational training spurred establishment of a new core curriculum based, not on the classical model, but on breadth of curriculum. (Levine, 2006, p. 25). How this new “general” education might look depended on reasons for thinking it necessary. Levine lists the following five:

1. the need to cultivate public spirit and civic intelligence;
2. the need to overcome one-sided intellectual specializations;
3. the need to overcome intellectual anarchy;
4. the need to uphold standards in face of leveling;
5. the need to help persons become more centered and reflective, in order to cope with the acceleration of change and of cultural productivity (Levin, 2006, p. 29).



Again, as in Cardinal Newman's formulation of desirable goals for higher education, we see a mix of public and private goals, and, as we shall see, a list that resonates with current lists of general education goals.

**Early 20th Century.** In the early 20<sup>th</sup> century, many universities were still offering an education that consisted of some mix of electives with vocational and occupational training. (Bok, 2006, p. 16) The percentage of mandatory courses again dropped and many students considered college a place for "...making social contacts and enjoying the good life." (Bok, 2006, p. 17)

Lacking the center provided by classical education, there was renewed pressure during the early 20th century to institute programs of common learning. Named general education, liberal education, or core curriculum, some kind of general requirement began to take shape during the beginning of the 20<sup>th</sup> century, and, for the most part, completed the process of replacing the classics as a set platform of learning for all (Bok, 2006; Rudolph, F., 1990, Chapter 21).

While various sciences had already become a well-established part of the university curriculum, enrollments in science electives were declining during the early part of the 20th century. At this point, it is interesting to consider what the preparation was for college and in particular for college general education science.

By the end of the 19<sup>th</sup> century, the structure of secondary school and undergraduate education was in flux. Dissent centered around the desired length of secondary school and, whether or not to include some general education portion of undergraduate education as the 13th and 14th year of secondary school (Levine, pp. 46-

47). Since secondary school preparation in science lays the groundwork for general education science in higher education today, I will briefly outline in the next section how science at the secondary level was presented and how the perception of the purpose of science instruction changed during the first half of the 20th century.

*“School” science.* It is instructive to look at the structure of science in the high school to get a feel for what basis was assumed to have been laid for science at the university level during the time when general education programs were taking shape. The Committee of Ten, called together and chaired by Charles Eliot, then president of Harvard, outlined the desired secondary school curriculum, including many recommendations about teaching science and conduct of science laboratories. The report expresses a sentiment surely echoed by college science instructors today:

As to botany, zoology, chemistry, and physics, the minds of pupils entering the high school are ordinarily blank on these subjects. When college professors endeavor to teach chemistry, physics, botany, zoology, meteorology, or geology to persons of eighteen or twenty years of age, they discover that in most instances new habits of observing, reflecting, and recording have to be painfully acquired by the students, habits which they should have acquired in early childhood.” (National Education Association, 1894, p. 15)

At the start of the 20<sup>th</sup> century, boundaries between high school and college were not as well defined as now and to stop school at the 8<sup>th</sup> grade was not uncommon. Secondary schools were not generally viewed primarily as places to prepare for college, since most graduates would not go on to higher education (Krug, 1961). *The Report on the Committee of Ten* included in its recommendations for science that students take astronomy and botany or zoology in the second year of high school, followed by a year of

chemistry, then a year of physics along with a course in anatomy, physiology and hygiene, plus a course in geology or physiography. The biology course, chemistry and physics were all to be one year courses. (1894). Some recommendations of the commission for physical science included these:

- That both Physics and Chemistry be required for admission to college.
- That there should be no difference in the treatment of Physics, Chemistry, and Astronomy, for those going to college or scientific school, and those going to neither.
- That the study of Astronomy should be by observation as well as by class-room instruction.
- That in secondary schools Physics and Chemistry be taught by a combination of laboratory work, text-book, and thorough didactic instruction carried on conjointly, and that at least one-half of the time devoted to these subjects be given to laboratory work.
- That laboratory work in Physics should be largely of a quantitative character.
- That careful note-book records of the laboratory work in both Physics and Chemistry should be kept by the student at the time of the experiment.
- That the laboratory record should form part of the test for admission to college, and that the examination for admission should be both experimental and either oral or written.
- That in the opinion of this Conference it is better to study one subject as well as possible during the whole year than to study two or more superficially during the same time.
- That in the instruction in Physics and Chemistry it should not be the aim of the student to make a so-called rediscovery of the laws of these sciences. (selected from the list of recommendations of the Committee of Ten, National Educational Association, 1894, p. 117 and following)

It is interesting to note how many of these recommendations deal with the laboratory portion of science education. As a center point of science instruction, a structured laboratory experience allowed students to get a taste of doing science. Labs remain central to science classes for both high school and undergraduate programs today.

One of the important recommendations of the commission was the suggestion that all students, regardless of whether or not they were college bound, should have the same course, rather than have courses designed for different populations. If the recommendations above were carried out as planned, and in place today, it could be argued that there would be no need for general education science in higher education. At the least, it would mean that college instructors could more safely assume that all students had had at least some hands-on laboratory training and a basic knowledge of chemistry, physics and biology.<sup>1</sup>

In the early 1900s secondary education was expanding rapidly, the percentage of those going to high school who planned to go on to college was dropping and the numbers of students who enrolled in physics was also dropping (Rudolph, J., Turning science to account, 2005). The response was creation of a course of general education science designed to appeal to more students and encourage them to study science in a way that might help logical thinking and build enthusiasm for science. Based on work of science professionals who were also educators and the influence of instrumentalism, a course labeled “general science” was envisioned as a way to help students develop a mode of thinking based on scientific method that they could apply to other disciplines (Rudolph, J., Turning science to account, 2005 ,p. 371).

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<sup>1</sup> According to national statistics compiled by the National Science Foundation in 2006, 63% of high school graduates had completed chemistry and 33% had completed physics. Only 12% had completed chemistry, physics and advanced biology. (NSF S & E Indicators, 2006). Depending on the high school it is likely that students today will come to college with preparation in at least biology and chemistry, but not all will have had physics or advanced biology. It is also likely that the depth and rigor of the science preparation will vary widely depending on state and school district.

During this time educators in Chicago and elsewhere developed the “project approach” to science (Rudolph, J., Turning science to account, 2005). The examples used tended to be based on inventions and engineering innovations drawn from the evolving technology of the times, methods of heating homes, of disposing of sewage, refrigeration, and the like. Students were given relevant science facts, then a problem that in some way related to the facts, often followed by some solution to the problem. The course evolved over time into more of an engineering course than a pure science course. By 1920 it was distributed across the country and between 1920 and 1950 was the most popular of all secondary science offerings. (Rudolph, J., Turning science to account, 2005,p. 386).

Popular as it was, general science failed in achieving Dewey’s aims, teaching students to apply methods of science to social and political questions. In practice, the esoteric goals of the general science course, developing lifetime thinking skills, gave way to concentrating on helping students pursue careers in engineering and promoting technological advance (Rudolph, J., Turning science to account, 2005, p. 384). The teaching of science over the early part of the 20<sup>th</sup> century eventually devolved into the “life-adjustment” curriculum with a focus on behavior rather than on intellectual attainment and was roundly criticized by working scientists who got involved in educational projects after WWII (Rudolph, J., 2002, p. 22).

*Undergraduate curriculum.* While secondary school was focused on the practical, college was for the upper classes in the early 1900s. According to a 1937 survey of employers, 70% thought a college education “guaranteed no useful abilities”

(Clark, 1998). Considering that, for the most part, the curriculum was still open to almost limitless freedom of choice, with, at one point, up to 55% of Harvard students graduating with nothing by introductory courses, (Bok, p. 16), this perception may have been justified.

Change was beginning by then however. In the undergraduate curriculum of the time, efforts to provide commonalities in education usually centered on requiring some kind of distribution of credits in addition to the major or common required courses. It was likely that the required courses included at least some science. The American Association of University Professors (AAUP) did a survey at that time of required orientation courses at American universities and found that it was common to include evolutionary biology and the scientific method, partly as a way of providing moral guidance. (Reuben, p. 163). At Stanford, a required biology course was linked to a required social science course “Problems of Citizenship” since the two topics were seen to be intertwined. Similar courses could be found at University of Chicago, Dartmouth and University of Minnesota (Reuben, p. 164, 165).

Reuben argues that science in the general education curriculum at this time was not only supplementing earlier religious training, but supplanting it, with moral guidance and ethics coming from natural and social sciences. Building the social order through understanding of social and natural science was the new focus of morality (Reuben, p. 174). During this period the groundwork seems to have been established for science as a fundamental part of the general education undergraduate curriculum.

Columbia and the University of Chicago both attempted integrative, ambitious general education programs during the early part of the 20<sup>th</sup> century. A course titled “The Nature of the World and Man” was initiated in 1924 at Chicago and was the model for one of the Core courses in the revised curriculum of the 1930s (Boyer, 2006). The four core courses were yearlong surveys, “The Nature of the World and Man” centered on Biology, and a second course included physical sciences, chemistry, geology and astronomy among them. Each of the four core courses would be in a sense self-paced. Students were not graded through the course, but took a six hour comprehensive when they felt they were prepared for it. Papers, exams, and quizzes were given as advisory grades, but did not result in credit on their own. The basic course structure centered on lectures, discussion sections and an optional laboratory demonstration every week. For the lab demonstrations students simply watched and did not conduct experiments themselves. Part of the underlying philosophy of the courses were the ideas that the “great men” of the university should be accessible to undergraduates, and that problems in science should be tackled by people from various departments in a coordinated way (Boyer, 2006).

**Post WWII through 1980s.** The role of science became increasingly important in American society after World War II. Technology based on science was seen as a vital factor in winning wars, and came to be regarded as vital in staying ahead of communist regimes during the Cold War (Rudolph, J., 2002). Harvard introduced a course titled “Research Patterns in Physical Science” after president James Conant noticed the confusion of men of all backgrounds when confronted with science (Rudolph, J., 2002, p.

50). Another important force influencing curriculum after World War II were returning servicemen returning to college after military duty. They used the G.I. bill to gain an education, and they expected real life practicality, an education that would prepare them for participating in the modern world and would lead to a desirable job. (Clark, 1998) Pressure to focus education on job training intensified with the influx of a large volume of students attending college in order to be more employable (Clark, 1998). At the same time counter-pressure to instill broader learning than that needed for the vocation or major sparked continued attention and interest in general education. The foreword to Wheelock's Latin text, written by the author's daughters, cites the G.I. Bill and the returning soldiers as the inspiration for his writing, an attempt to provide an approach to a classical subject that would come alive for these students (Wheelock, 2005).

Science was assumed to be a necessary part of a college education for all by the 1950s, partly as response to the perceived need for scientists and technology workers, both for reasons of increasing national security and for societal progress (Kilpatrick, p. 171; Rudolph, 2002, p. 59), but also for the benefits that thinking scientifically could bring to non-scientists (Kilpatrick, p. 328).

Although Dewey's idea of scientific method had been misunderstood as a "cookbook" approach of rigid steps, and was rejected by working scientists, including those who got involved in the push to revitalize high school science teaching (Rudolph, 2002), reformers believed that the empirical, rational way of thinking should permeate education. A 1960 report by the Education Policies Commission of the National



Education Association said that the pursuit and use of scientific knowledge was the most fundamental force changing the world (Rudolph, J., 2002).

Not everyone during the second half of the Twentieth century thought science and technology were having a positive effect on society. However, even those who were concerned about downsides of science and technology felt that learning science was necessary, since modern science was transforming everything about American life. A broad spectrum of the population needed to be prepared for the difficult decisions that would result from increasing reliance on technology (Seaborg, 1966). A prime example of a science issue that aroused mixed feelings (and does so today) is the issue of how to use nuclear fission. During my own undergraduate education in physics in the 1960s I remember heated discussions over the benefits and threats posed by the use of nuclear reactors for power generation.

Tension between concerns about the possible uses of science and an abiding perception that everyone should have some science training has continued to the present. But the question of what students need to know is complicated by the explosion of research that followed WWII. The question about what all undergraduates should know about science has still not resulted in a clear consensus, as we shall see in the present state of general education science.

**1980s to present.** Both before and during several reform waves following WWII, educators have wanted to achieve more with education than just preparing students for the workforce. As Bok (2006, p. 46) points out, general education is the most common target of curricular reform and the first place reformers go when it seems

necessary to meet a perceived need of society, whether it be understanding of Western culture or development of critical thinking. On the other hand, pressure to add more to the major, as knowledge expands and more specialties emerge, means less time within the major courses to make connections to other disciplines, to teach about ethics, to reinforce writing skills and math skills and generally help the student pull the trailing threads of an education together into a coherent whole. If students are to be broadly educated in fields beyond their major it is most often done with a separate set of general education courses organized in some way to encourage students to look beyond the specialty. A flurry of reports urging general education reforms in the 1970s seem to have stemmed from a perception that general education was needed and was not succeeding (Marinara, 2004, p. 2). Something similar seems to have been happening during the last ten years as assessment efforts, urged by the public and by funding agencies, try out ways to measure the value of an education.

A perennial problem is that there is not adequate time in any of the general education required courses to learn in ways that are both deep and broad. How much is enough is something that will be determined by the model used by each institution. Whether that “enough” reaches students, will depend on how well the model is implemented and understood by all stake holders. In the distribution model most common in American higher education, general education courses are generally not connected to each other or the major. Science is sectioned off, as are history, English, and other staples of general education, and may seem irrelevant to ultimate career paths and goals.

From the 60s through the present, a series of reports critical of education in the public schools have cited student's poor performance in science as a danger sign and have called for reform (Rutherford, 2005). Recently higher education has also come under criticism with books such as "*Our underachieving colleges*" (Bok, 2006), "*Talking about leaving*" (Seymour & Hewitt, 1997), and "*Academically adrift*" (Arum & Roska, 2011). While much concern in these and other analyses of higher education is directed toward preparation of students in their major fields, general education, including science education, has often been a focus for reform.

George Mason University instituted a general education program, PAGE, in the 1980s. I will examine it in more detail in a following section on general education at Mason. National organizations such as NSF, and AAC&U have pushed for reforms, and there is currently much interest in science education research done through science departments rather than through colleges of education. The same questions still pertain, however. "What is the purpose of general education, and in particular of science within general education?" and "When goals for a course are specified are they being achieved?" Since some of the more recent focus on general education reform is concentrated on curriculum design, I will outline common current models in the following sections.

**General education models.** A study by V.R. Smith, Brunton, & Kohen (2001) categorizes general education programs as either those that require the same core curriculum of all students or those that allow students to select from a broader menu to fulfill a set of distribution requirements. Additional pieces may or may not be present,

capstone courses, undergraduate research requirements, and learning communities may all come under the heading of general education, but the majority of students get most general education by selecting from a “menu” of courses (Hart Research, 2009).

One particularly useful analysis sorts general education arrangements by their structure within colleges and universities (Newton, 2000). Three potential models show the different approaches and perceived purposes of general education as structured in different higher education institutions. Most common in research universities is the distribution, or in Newton’s formulation, “scholarly discourse” model, involving choosing courses from an approved “menu”(Hart, 2009; Newton, 2000). Typically general education science courses in this model are survey courses designed to serve double duty as general education and introductory courses for students majoring in the science discipline. Less common is the “core curriculum” structure, characterized by a standard set of introductory courses for all students. A good example currently is Columbia University with its “Frontiers of Science” course for all freshmen. Finally, some schools, generally smaller private liberal arts schools, use the “great books” model. All students read the classics as a basis for all studies and majors. Great books is probably closest to the heritage of the colonial college. Which model is used is often a function of the type of institution. Research institutions with strong departments and disciplinary focus commonly use a scholarly discipline model plan with rigorous introduction to the disciplinary science courses taught by experts in the field. Core curriculum is a possibility for all types of institutions and fits well when general

education aims to prepare students for their role in society and as citizens in a democracy. (Newton, 2000)

Each of the models has different strengths and weaknesses. For science, “pick two from the menu” distribution models present particular problems. The sciences already exist as disparate entities, often quite different in approach as well as content matter. Establishing goals raises a number of questions. What is it about science that students need to learn? Should all students take some kind of integrated science course that includes “big ideas” from major science disciplines? Alternatively, would it be preferable to have students immerse themselves in one discipline in a sequence of courses to gain depth? If so, does it matter which discipline is chosen, biology, geology, physics, environmental science, or chemistry? Should labs be part of the requirement and if so where should their emphasis lie: inquiry experiments, problem solving, replication of important experiments in the discipline, lab techniques, statistical analysis of results, report writing? What arrangement will best serve students both during their undergraduate years and afterwards as they move into careers? The answer to such questions are not clear and will depend on what goals are seen as foundational.

Even when goals are selected, questions rise at the institutional level as to how best to implement them. If general education courses are guided by institutional policy and goal statements, how are these goals communicated to instructors and students? Large enrollment courses in general education science are common at research universities, and are more likely than courses in the major to be taught by adjunct faculty or graduate students who may have minimal training and supervision (Hersh & Merrow,

2005). Lab sections are most commonly managed by graduate students who may not have been introduced to the wider picture of what learning goals the course is supposed to serve. It seems reasonable to assume that all instructors need to know the “big picture” reasons behind requiring these courses if they are to incorporate institutional goals systematically. The questions remain regarding whether any instructors, not just contingent and graduate teaching assistants, are aware of the broader goals of the courses they teach. The following section looks in more detail at frequently cited goals for the science within general education.

### **Contemporary Understanding of Goals of General Education Science**

Science is one area that is almost universally included in the general education curriculum (Shoenberg, 2005, p. 9, Hart, 2009). As outlined in the discussion of general education history in previous sections, the reasons for including science have changed over the last century. The reasons for including it in today’s curriculum vary somewhat, but seem to stem mainly from a perception that, since science and technology are major forces in society, graduates should have some understanding of science process and methods, and should understand the big ideas in science that underlie current science research and discoveries. I will look in much more detail in the research chapter at stated goals from a number of contemporary higher education institutions to demonstrate some of the range of possible goals. In the following sections I will review some goals extracted from the history of general education, outline goals listened by several national organizations for general education science, then discuss some commonly cited goals in more detail.

**Historical goals of general education science.** Which view of the purpose of science teaching and the meaning of scientific literacy predominates seems to be dependent on the political and cultural climate of the times. In the 1800s, with science beginning to flourish, the German research university was a model for American higher education institutions. Educators placed a high value on science, partly for its role in fostering independent thinking (DeBoer, 2000). After World War II, science education was considered vital as a way to produce scientists and a public sympathetic to science in view of national security interests (Rudolph, J., 2009).

A study of scientists and science education by Robert Carlton of the National Science Teachers' Association in 1963, found that, at that time, content had been the primary focus of science teaching and little attention was given to the relationship of science and society. (DeBoer, 2000). The separation of scholarship into two camps is highlighted from another perspective in *The Two Cultures* where C.P. Snow made the point that there was a gulf between science and technology workers and those educated in literary fields. (Snow, 1969). Snow advocated technology as a solution to the problems faced by underdeveloped nations and credited science with power to avert war and disaster. In both cases, science content knowledge seems to have been seen as a necessary driving force of cultural change.

Dix et.al. (1990) advocate approaching science through interdisciplinary education, comparing inquiry in science to inquiry in the arts, music, and poetry. This formulation emphasizes that science differs from other disciplines in that it relies on measurement to test hypotheses. In contrast to the arts, science claims are valid to the

extent that they are measurable. A passion for truth motivates scientists. Scientists are expected to be ethical, rebellious, curious, and pervaded by doubt, all of which teachers should convey to students.

Hammer and Dusek (2006) follow science processes and thought as they appear through history and in various science disciplines and advocate that students learn the importance of the social context of science, how it changes with time, with field of study and with philosophy of its practitioners.

Often, goals for science teaching center on pedagogy. Examples include problem-based learning (Keller, 2002), just-in-time teaching (Novak, Patterson, Gavrin and Christian, 1999), peer instruction (Green, 2003; Mazur, 1997, Slater and Adams, 2003), studio learning (Beichner, 2009) or some other alternative. Embedded in each of these are goals for student learning, whether it is problem solving, student engagement, mastery of concepts, or something else. It can be quite difficult to untangle science literacy or reasoning goals from pedagogy. A complicating factor in untangling science pedagogies and literacy or reasoning goals is that most science courses include lecture and laboratory and possibly recitation sections, often only loosely connected. Lecture based courses can most easily promote content goals, while laboratory experiences are a natural setting for practicing science process. It seems likely, as Stage and Kinzie (2009) found in their study of reform of undergraduate science teaching, that changes in teaching practice also engender changes in philosophy and presumably in ultimate goals.

**National organization goal statements.** In its report on assessment the AAC&U describes the process of assessment as “a process of inquiry and improvement”



(Leskes & Wright, 2005). The process starts with setting goals, moves to finding evidence of achievement of goals, then to implementing changes. A way to approach goals for general education science is to look at desired goals outlined by national organizations with a stake in science education for the general public. The paragraphs that follow outline some of these goals which I will return to when discussing the collected goal statements for a variety of higher education institutions in the results chapter.

The Association of American Colleges and Universities (AAC&U, 2005) in their initiative for general education, *Shared Futures*, suggests that students should have the opportunity to explore science with a global focus. They note the value of educational techniques such as problem based learning and suggest studies involving such current social issues as disease, environment, and natural resources.(AAC&U, Shared futures, 2005).

In another AAC& U document some suggested purposes of general education are listed as follows:

- Development of prerequisite skills needed for later work
- Development of abilities that cut across disciplines, like critical thinking or problem solving
- Development of general knowledge about particular disciplines and experience with different modes of inquiry
- Collegiate socialization – learning how to “do college” by learning how to use a library (or the Web), or how to plan and carry out an independent intellectual project. (adapted from Ewell, 2004, p. 10)

The National Research Council has been working since 2008 on a project to collect and disseminate “promising practices” for undergraduate education in science,

technology, engineering and math (STEM) (Singer, 2008). While STEM education refers primarily to majors in those disciplines, much of what promotes increased learning for majors should have relevance for learning in general education science as well.

Specific goals for STEM majors include:

- Master a few major principles well and in-depth
- Retain what is learned over the long term
- Build mental framework that serves as a foundation for future learning
- Develop visualization competence including ability to critique, interpret, construct and connect with physical systems.
- Develop skills (analytical and critical judgment) needed to use scientific information to make informed decisions.
- Understand the nature of science
- Find satisfaction in engaging in real-world issues that require knowledge of science. (adapted from Singer, 2008).

Project 2061, an effort sponsored by the American Association for the Advancement of Science to help all Americans achieve science literacy (Roseman & Koppal, 2006), includes a comprehensive set of learning goals that disciplinary experts have identified as foundational. The expert teams evaluated goals based on: utility, social responsibility, intrinsic value of the knowledge, philosophical value and childhood enrichment. (American Association for the Advancement of Science, 1990).

The criteria above could be used to evaluate both general education science goals at the university level and specific goals within courses.

Distilled from the lists cited above, goals of general education science that are nearly universal include scientific literacy, scientific reasoning, and critical thinking which I will discuss in more detail below along with other frequently mentioned goals for these science courses.

**Scientific Literacy.** Indira Nair, chair of the AAC&U's Shared Futures Global Learning Leadership Council differentiates scientific expertise and scientific literacy. Literacy is being able to find information, understand basic meanings and ask the right questions to use science information. (Nair, 2011). She points out that the National Science Education Standards of the National Academy of Science go farther in expecting that being able to predict natural phenomena is included in the literacy definition. Nair states that predicting requires formal understanding of science that not all can achieve, but it is at least a potentially valuable element of general education science.

Some approaches to scientific literacy are straightforward, involving knowing about how the scientific process works and have a basic understanding of the “big ideas” in science (Trefil, 2008; Project 2061, 1989; NSF, 2006). An assumption here is that all educated people need a basic understanding of well-established foundational concepts and facts in the sciences. Tests based on these big ideas have been used to assess general knowledge about science in various countries

**Scientific Reasoning.** One approach to teaching undergraduate science is to ask students to read science articles and analyze them for elements of scientific reasoning. Ronald N. Giere is an exemplar of this approach. His books outline six step approaches, not for doing science, but for analyzing scientific research papers (Giere, 1997; Mauldin & Lonney, 1999). His six-step plan asks students to: identify the real world aspect under study, identify the model that the science study is using to represent the real world, state a prediction based on the model, identify a data set related to the prediction, state whether the data support or invalidate the prediction, and if they

support it, ask if an alternative hypothesis exists that also explains the data. Giere discusses statistical hypotheses as well and ends with a section on decision-making based on both science and costs of acting or not based on the science.

Scientific reasoning in Giere's formulation is reasoning about science claims, not reasoning that occurs when doing science, though the two are obviously related. Such cut and dried steps do not model science as it actually unfolds, but they can be an effective way to examine and evaluate the claims of scientists as reported in popular media, peer reviewed journals, talks, and posters. Being able to sort "good" science from claims of pseudo-science is part of the science reasoning goal and often included in goal statements about science education.

**Critical thinking.** Writing about teaching critical thinking, bell hooks examines the value of education in giving students a voice in a democratic society. While the issues she examines here have to do with race and gender, it is important to think about how a good understanding of science, its culture, processes, basic concepts and findings, can help all students have a voice when it comes to science issues (hooks, 2010). The idea that science is a good training ground for critical thinking and problem solving is not new with this millennium. Science as a way of thinking that could be applied to any other discipline was behind some of the secondary school curriculum changes in the 1900s and is foundational to John Dewey's educational philosophy (Rudolph, J., 2005b, p. 387).

While the idea of a "science method" with well-defined logical steps in an iterative cycle seems to have given way to discussion of the a messier, culturally situated

scientific process, the evidence based requirements of acceptance of premises in science means it is still a good candidate for analyzing problems and gathering evidence that can be used to construct solutions.

**Science and society goals.** A purpose of the general science curriculum in secondary school in the early 1900s was to “...teach students to use their rational faculties to remake the material world for the advancement of humankind” (Rudolph, J., 2005b, p. 384).” Rudolph reports that in the same time period physicist E.P. Lewis suggested that truth and virtue were outcomes of studying science. Science Education for New Civic Engagements and Responsibilities (SENCER) was established in 2001 under an NSF grant to promote science and civic responsibility through science education that starts with public issues or problems that can be addressed with science (SENCER, 2012). The National Science Foundation currently offers grants for research on the intersection of science with questions of ethics and social concerns (NSF, 2012).

**Reflective thinking and misconceptions.** A hot topic in science education is the study of student misconceptions (Hammer, 1996). Misconceptions seem to be a product of students producing a mental model of how the world works based on analogy between the subject under consideration and their real world experience. For example, it is difficult for students to de-link “ closer is warmer” which they know from experience, and the angle of incidence explanation of why there are seasons on earth.

Many of these misconceptions have been uncovered in fields of science from biology through physics and astronomy (Bowling, et.al., 2008; LoPresto & Murrell, 2011; Nehm & Reilley, 2007). It might be desirable to approach some misconceptions

head-on, but it takes considerable effort to change them and tackling them raises the question of which of them are worth taking teaching time to sort out. On the other hand, finding a way for students to identify their own misconceptions (or pre-conceptions or unfounded assumptions), and to use reasoning to sort through them and come up with models and applications that have an abstract component based on science understanding, might provide another way of thinking about scientific reasoning. Students who think that space agencies put telescopes in orbit so they will be closer to the stars should quickly understand that this could not be the reason after they have learned about concepts of scale in astronomy and understand the relative distance from earth to orbiting satellites and the stars. Encouraging a reflective component in science classes may be a start toward helping students to think critically about their own science beliefs and understanding (McDonald & Dominguez, 2009).

**Imagination, and creativity.** Although imagination and creativity are features of science investigation they are not on the radar screen in most science teaching until perhaps the graduate level, if then. Both imagination and creativity may have negative connotations in the context of learning science logic and teaching the science process. They could be perceived a kind of license for “anything goes”, regardless of evidence in physical reality. However, as hooks points out (2010) imagination is valuable as the place where synthesis and deep learning happen. It is through imagination that links are made between disciplines in the sciences and with science and other fields of study.

**Translating goals through pedagogy.** Shoenberg (2005) argues that American society benefits when students have experienced a coherent program of general

education courses. When integrated and done with intentionality the general education program should prepare students to make “effective life choices, understand and function well in a diverse national and world society, and contribute to their communities...” (Shoenberg, 2005, p. 23). Science is obviously important in the world the students are preparing for, but what does a science course look like that prepares students to do any of these things?

Gamson (1984) speaks of the role of “lively academic communities” in creating a culture where students feel they can trust each other and the instructor and can safely ask questions and take learning into their own hands. She quotes a student in an exemplar program as saying “if I don’t understand a particular concept or I don’t agree, I will question it until I do get the understanding. I use the tools I have learned in FLC in the other courses that I am taking. I don’t take things at face value, I go and I question. I have found that while it takes a lot of time and effort, if you go to professors and you bug them enough they’ll answer your questions” (Gamson, p. 90). This attitude of questioning is not always cultivated in survey courses in the sciences, there simply isn’t time to get through the material and also address what may seem to be distracting questions. Yet science is built around both questioning the natural world and questioning the models science has constructed to explain and predict events within it.

**Liberating education.** Discussing the various ways 14 different programs at 14 different institutions approach liberal education, Gamson says of institutional approaches to education:

“...creating the conditions of a liberating education is as much a sociological question as a philosophical one. If colleges and universities are to be

environments in which such an education takes place, they must design *structures* that overcome the isolation of faculty from one another and from their students. They must build *communities* that encourage faculty members to relate to one another not only as specialists but also as educators. And they must provide continuity and *integration* in the curriculum. (Gamson,1984, p. 84)

The AAC&U's (20007) current LEAP initiative on liberal learning outlines high impact practices that affect student engagement. While many of the items on the list of high impact practices may be valuable for learning and integrating science education, the one that stands out as a “natural” in general education science is the practice of undergraduate research. The goal here is to “involve students with actively contested questions, empirical observations, cutting-edge technologies, and the sense of excitement that comes from working to answer important questions. (Kuh, 2008,p.10).

For instructors, this may entail knowing about current science education research in order to think past instructor models of student learning to be able to interact in different ways with learners (Hammer, 1996). Evident in the history of science as part of the curriculum in the U.S are tensions between content and application, between science as a social force and as a mental discipline, tension between science as a necessary subject for a citizen of a democracy and as a cultural heritage to appreciate. Though these factors are not mutually exclusive, they are also not always completely compatible. Teaching science in an effort to support and extend critical thinking and creativity looks different from teaching science as a kind of practice apprenticeship. Goals, explicit or not, provide direction and rationale for science teaching.

**Assessment of goals.** Once goals are selected, a curriculum designed and effective pedagogies in place, the loop must be closed with assessment. (Mestre, 2012).



Evidence for achievement of the learning goals as outlined during NRC workshops is also relevant. Evidence for goals listed above includes:

- Mastery of broad content or concepts
- Skill development
  - Scientific skills
  - Higher-order thinking skills
  - Life-long learning skills
  - Interpersonal skills
- Affective domain
  - Motivation to learn
  - Overcoming barriers to learning
  - Addressing values and attitudes about science
  - Behavioral changes – including retention (Adapted from Singer, 2008)

Through assessment, it became plain that general education science might not be adequately addressing some learning goals at Mason. The general education group set up in 2010-2011 responded by considering changes to learning goals, and curriculum. How general education science will change based on the current effort will depend on the institution and the faculty members who choose to be involved in change. Once new goals are in place, assessment can help ensure that courses stay on track.

Ranging from study programs for older adults at a technical college, to a learning community at a state university, each of the programs surveyed in the *Liberating Education* text (Gamson, 1984) have different approaches that depend on the purpose and character of the institution. One size won't fit all, but it is important to look for commonalities in approach or goals or values that might be foundational for a wide variety of liberal arts or general education programs in order to sort out the role science might have in the curriculum (Gamson, 1984).

In a report extending lessons learned about K-12 science teaching to undergraduate education Roseman and Koppel (2006) identify three areas that are important in improving science education as: “(1) identifying the goals for learning, (2) designing a curriculum or sequence of learning activities that will enable students to achieve the goals, and (3) fostering a climate that will support continued monitoring, evaluation, and improvement over the long term.” (Roseman and Koppel, 2006, p. 326).

### **George Mason and General Education Science Reform**

In this section I will give a brief overview of general education science at Mason, then discuss issues that affect reform processes in general: alignment of goals within and across institutions, and potential obstacles to the reform process.

**General education science at Mason.** Mason’s current reform effort began with setting new goal statements in 2011 and has recently offered small grants to faculty members for developing or revising general education science courses. Goals matter, as Dewey points out, not as ends to be reached, but as way stations in learning (Dewey, 1933, p. 15). In this section I will examine goals for general education science laid out by some national organizations with an interest in science education, then consider other broad learning goals for general education science.

George Mason University developed a general education plan to supplement distribution requirements in place in the early 1980s. The Plan for Alternative General Education (PAGE) program at George Mason University in the 1980s was begun under a new president, George Johnson, during a time of widespread general education reform. PAGE was offered as an alternative to the distribution program and ran

concurrently with it (Blois, 1987). A sweeping reform movement, with apparently broad support from faculty, two decades later it has become the heart of the Honors College and New Century College while the more traditional distribution model prevails for the majority of undergraduates.

From 2003 to 2008 the Office of Institutional Assessment at Mason developed a test of scientific reasoning for all students at the school. Since both majors and non-majors take a series of general education science courses, a team of faculty members and assessment specialists developed a pre-post- assessment to give in the general education science classes. In the 2010/2011 school year the College of Science (COS), along with members of Institutional Assessment and the general education program, began examining the general education program goals. COS faculty were invited to a series of open meetings to discuss their concerns and impressions of general education science and then to draw up a revised set of goals for the program as the first step in revitalizing the curriculum.

Copies of general education goals that were in use prior to 2010/2011 and the current revision as well as the “Life, Liberty, and Pursuit of Happiness” document for general education at Mason are included in Appendix A.

**Alignment of goals and student learning.** While it seems obvious that goals of the university, goals of instructors and goals of a course as perceived by students for general education science should be roughly the same, it is not clear to what extent goals of general education science are being achieved at Mason. Goal statements are currently used to guide assessment (Institutional Assessment George Mason University), but it is

likely that not all aspects of general education science goals are being applied to teaching and learning within specific courses either at Mason or, for that matter, at most higher education institutions (Ewell, 2004). The goals that belong to the program of general education may not align at all with the goals set by individual instructors or departments for the courses that satisfy the requirement, particularly when courses serve as both general education and majors courses.

There is little information about how students choose courses and how they perceive them (Ewell, 2004). Within a distribution system, students might choose courses based on genuine interest, perceived value within a broader program of study, or the time of a day a course is offered. Whether students take general education courses early in undergraduate education or toward the end of their studies can also be significant. For example, if a general education course goal is to experience inquiry in science in order to practice inquiry within the major, postponing general education science until senior year will not be as effective as taking the courses early.

The next sections explore some of the approaches to science learning that should be considered when sorting out how science contributes to what we value in college educated members of society.

**Institutional goals.** Broad areas encompassed by general education goals include skills, ways of knowing, preparation for citizenship in a democratic society, grappling with diversity, issues related to culture and global society and ethical and moral reasoning (Shoenberg, 2005). Courses clearly aligned with one or more of these purposes would be a start toward building a coherent set of liberal learning experiences

for all students. However, when considering how to implement these goals within specific programs and courses, a number of problems arise, including the issues of allotted time, articulation, and, most important for this report, transmittal of goals to individuals teaching and taking the courses.

First, it is difficult to understand how any one of the broad goals listed above could be met in, typically, 8 semester hours of laboratory science. Many of the desirable goals are not exclusive to science, citizenship and societal goals in particular. Science reasoning, content, and skills need to have some amount of transferability to other disciplines if they are to have more than ephemeral use for non-science majors. It is important to have linkage with other general education courses and the major, something difficult to achieve with a distribution system of general education, unless there is deliberate integration.

Another concern is how of general education science courses transfer from one state institution to another, from state to state, or from private to public institutions. Though some states specify lists of courses to meet requirements, few states delineate specific content that will satisfy particular general education requirements (Shoenberg, 2005, p.10). Though I have chosen not to deal with these issues here, they should be considered whenever restructure of general education is being considered since anything done at any of the linked institutions affects what needs to be done at the others.

The next sections deal with expectations of individuals teaching and taking general education science courses and with barriers to transmittal of goals.

**Student expectations.** Some high school and college students in focus groups conducted in Indianapolis, Indiana, Portland, Oregon and Alexandria, VA in 2004 indicated that they think the best reason to go to college is to open up career choices leading to a greater variety of job opportunities. The second most cited reason to go to college was to gain skills and knowledge needed for a job. Third was gaining life knowledge helpful both on and off the job, and forth was to gain knowledge, ethics, etc. that would be important for professional success (Hart Research Associates, 2004). In the same survey, high school students indicated very little familiarity with the term liberal education and in some cases had extreme misunderstandings, not realizing it could include science and math, not associating it with universities, but only with liberal arts colleges, or believing the term means politically liberal. College students who understood the term sometimes appreciated the idea of a broad education and the possibility of discovering new interests, but they also mentioned their perception that general education courses take time that could be spend on the major (Hart, 2004). Others felt that college general education repeats much of what they had already learned in high school. (Hart, 2004). In *General education and student transfer*, Robert Schoenberg (2005) speaks of student perceptions of the purpose of general education, saying that the purposes of general education courses are often not clearly articulated by the university and only vaguely connected to individual courses. Students are confused by the disconnect and see general education courses as “evils necessary to endure, as obligations to be ‘gotten out of the way’ before getting on to their majors (Shoenberg, 2005, p. 4). College juniors and seniors commonly reported that their courses didn’t

match goals of general education, were not connected to their majors and hadn't gone beyond their high school training (Shoenberg, 2005, p. 5). To get perspective on general education courses in science it may be instructive to consider how courses are presented and how they are perceived by majors in the discipline. This is particularly relevant when courses for general education are also courses for students majoring in the discipline. One of the top concerns for students leaving science fields for other majors is their perception of poor teaching (Seymour & Hewitt, 1997, p.46). Other reasons that may be relevant to general education include problems related to class size, and teaching approach, as well as inadequate high school preparation (Seymour & Hewitt, 1997, p. 47). If these factors were important for students with high test scores who had begun majors in the sciences or math, it seems reasonable to assume that in the same classes, general education students might have some of the same concerns.

Although instructors in general education science don't have control of high school preparation, being aware of areas in which many students may be inadequately prepared may be helpful in shaping appropriate instruction. Teaching approaches will be addressed in the following section on faculty development. Though class size was not listed as frequently as poor teaching in reasons student might consider switching out of a science major, it was important and should be an area of concern. General education courses in science are sometimes seen as a potential source of majors in science, but more important may be the long term effects of education for citizenship and whether students in these classes develop an interest in scientific topics that require decision-making.

**Faculty expectations.** It is probably not surprising that most general education science courses at Mason are structured as survey courses and are also introductory courses for majors in the discipline. Faculty members learned science, in most cases, by taking survey courses that laid the groundwork for more specialized courses, and most textbooks written for this level cover large amounts of material designed for introductory courses in the major. This “standard model” seems logical and straightforward, but goals such as ethical and moral reasoning, the role of science in society, and even the logical and philosophical underpinning of scientific thought are overwhelmed by the sheer volume of material that must be covered in one or two semesters. Approach to teaching and learning in general education seems to vary somewhat based on discipline, with faculty in science likely to concentrate on surface learning and learning for specific occupation (Laird, Shoup, Kuh & Schwarz, 2008). Since many general education science courses serve double duty as introductory majors courses this survey approach is understandable, but not necessarily the ideal approach for non-majors.

As with many universities, Mason draws faculty to teach general education science from a pool that includes full professors, other tenured and tenure track professors, contract (term) faculty, and adjunct faculty. In general, adjuncts, term faculty and graduate teaching assistants cover the laboratory sections of the courses, though in some cases they may also teach lectures. In addition to teaching, full time faculty are generally involved in research, adjuncts are employed full or part time elsewhere, and teaching assistants have classwork and may be starting their research projects. Teaching general education is not likely to aid the careers of any of them significantly, and while



most do care about the quality of the courses they teach, there is little time or energy for working on broader curriculum reforms (Hersh & Merrow, 2005; Kirp, 2003, p. 69).

Fairweather (2005) found that hours spent teaching have a negative effect on pay for full time faculty who are both teachers and researchers. Time spent on curriculum development or redeveloping a course to incorporate major changes in approach will not pay off in financial terms. It may not pay off in student ratings of instruction either since students may also be resistant to new approaches (Dancy & Henderson, 2008).

The challenge of keeping up with current pedagogy and implementing it is another barrier to reform. Even when teaching methods have been shown to significantly increase student learning, the barriers to adoption are high. *Barriers and Promises in STEM Reform*, a paper commissioned by The National Academies Board of Science Education, reports that faculty reluctance to change is an important factor impeding reform (Dancy & Henderson, 2008).

It will be important during the course of this study to keep in mind the way individual faculty members may see their role in general education. Mary Wright, in a study of faculty beliefs about teaching, writes that most faculty members see themselves as valuing teaching more than their colleagues (Wright 2005). She cites a study of faculty in research and doctoral institutions that found that faculty felt they valued teaching more than chairs, deans and administrators did (Diamond & Adam, 1997 as cited in Wright 2005). Faculty members are also often protective of autonomy in the classroom and wary of interference from outside (Shoenberg, 2005, p. 19). Wright went on to evaluate departments at a major research university where she found “instructional

congruence”, individuals believing their ideas about teaching line up with institutional beliefs. This study is important for several reasons. Beliefs about general education may either generally match an individual’s perception about those of the institution, or may be deliberately divergent. Units that Wright found to be convergent had cross-departmental discussions about instruction, and were more likely to have opportunities for team teaching and peer review. Those units that were not convergent, where faculty perceived their views and those of the institutions or their peers did not line up, sometimes had one or two individuals considered expert in teaching. Instructors might have had conversations about teaching in administrative settings, but lacked the peer network of the congruent units. If similar patterns hold for beliefs about general education in the sciences, it may point to ways in which the institution can encourage congruence by fostering good interdepartmental peer relationships, building opportunities for team teaching and embedding peer review in the college culture. The second reason that Wright’s study is interesting is that the methods followed by Wright, and some of the questions asked, may be valuable for the study of alignment of perceptions about general education as well.

Programs built by groups of enthusiastic faculty - usually with support from administration and departments - may fade away when the originators go or when a new set of administrators and faculty come in with fresh visions and plans. An example of such a program in Virginia was James Madison’s Liberal Studies Program (LSP), designed in the 1980s by faculty with a program of review and oversight. Its original program for the liberal arts was apparently widely supported by faculty (Smith, V.R.,

Brunton & Kohen., 2001). However, the LSP menu-driven general education program was subsequently replaced with something more along the lines of a core course format with various clusters with embedded packages of classes designed to implement some 100 learning objectives. Part of the impetus for change may have been external pressure from new state assessment standards, at any rate, there apparently has been much dissent on the part of the faculty. Some complaints included perceptions that the new core curriculum format was implemented quickly without time for invested faculty members to respond (Smith, V.R., Brunton, & Kohen, 2001).

*Faculty development.* Faculty often do a poor job of communicating goals of their courses to students (Shoenberg, 2005, p. 5) And yet, as Singer points out “Metacognition and explicitly teaching the nature of science are promising because of research in cognition” (2008, Linking evidence and promising practice, para 11). If students are expected to become reflective learners, it is up to faculty to help them understand purposes and find connections to spur reflection.

For example, if a central role of general education science is determined to be helping students learn to pose and solve problems then it will be necessary for faculty to become adept at fostering a questioning attitude in students.

NSSE lists a series of practices that spur deep learning such as:

- Integrating ideas from different sources
- Discussing ideas with faculty members outside of class
- Analyzing the basic elements of a theory
- Synthesizing and organizing ideas
- Making judgments about the value of information
- Applying theories to new situations

- Examining strengths and weaknesses of your own ideas. (Laird, Shoup, Kuh & Schwartz, 2008)

Any of the practices above lend themselves well to science, but few of them are implemented consistently in traditional general education science courses. It will take creative restructuring or innovative use of technologies, but it should be possible to help faculty members incorporate a broader mix of practices in the lecture classroom that will help students learn.

Thomas Kuh, writing for the AAC&U about high impact practices that affect student learning, cites the National Survey of Student Engagement's finding that faculty guidance in a student research project helps learning (2008, p. 20). Kuh also points out that what faculty members value influences what students do. Faculty members who support and work to foster undergraduate research increase the likelihood of student involvement (2008, p. 22). A problem with many of the high impact practices, including undergraduate research, is that few students taking a course in general education science will have the opportunity to engage in it.

On another level, perhaps just developing some kind of forum for students to articulate and test their own ideas with appropriate guidance would be a technique to help students develop both expertise and competence at the level needed for effective citizenship. One promising practice in the use of Learning Assistants (LAs) in connection with large lectures (Otero, Polluck, McCray and Finkelstein, 2006) both as a way of improving student performance and preparing future science teachers. LAs are recruited from top students who have taken the class. They are used in future semesters to

help with group activities. As a science teacher at Hampshire College pointed out in a discussion about dealing with female students, “The rightness of answer inhibits the free-flowing and critical inquiry that education should promote...The word “dumb” came up in many of our student interviews. It casts a certain amount of judgment on the kind of teaching style where the goal *is* to make the student feel dumb” (Gamson, 1984, p. 108-109). Use of LAs and similar techniques using peer instruction could help open up discussion while guiding it toward correct thinking.

**Institutional barriers.** Institutional barriers to effective learning in general education science can also be significant. Institutional barriers include factors such as class size and location, in addition to staffing and faculty training issues. (Dancy & Henderson, 2008)

One high barrier is the issue of transfer. Students who come into a four year college from two year institutions have often completed most if not all of the general education requirements. As Shoenberg (2000) points out, this means that the courses at the two year institutions have to be broad enough to be accepted at a variety of four year institutions, and the four year institutions have difficult decisions to make when courses at either institution are innovative and difficult to categorize. Students anticipating transfer want to be sure the majority of their coursework goes with them. Institutions want to ensure that their degrees have meaning and substance. Shoenberg (2000) mentions the credit hour as a driving force behind distribution systems for general education. Credit is a medium of exchange, earn some here, move them there, and eventually pay off the general education debt. Any kind of connection between courses

is difficult to establish and courses that are non-standard are suspect for the receiving institution (Shoenberg, 2000).

Class size presents other potential barriers to reforms aimed at pursuit of learning goals. Common wisdom holds that smaller classes would allow better teaching, though current methods involving peer instruction seem to show learning gains even in large classes (Smith, M.K., Wood, Adams, Wieman, Knight, Guild & Su, 2009). Excellent lecturing has been shown in some studies to lead to only small learning gains compared to the same course taught by less accomplished lecturers (Slater & Adam, 2003). Many of the goals that are desirable in general education science require students to make connections and to integrate learning from various sources, something that transmissive teaching alone is unlikely to help them achieve. As hooks puts it “When we as a culture begin to be serious about teaching and learning, the large lecture will no longer occupy the prominent space that it has held for years.(hooks, 2010). Evidence from a survey of interaction patterns in college classrooms supports the idea that participation rates are low in classes that are mainly devoted to lecture (Nunn, 1996). However, passivity is not confined to lecture classes as attested to by those who have tried to incorporate active learning in the classroom (Lucas, N.L, 2010).

In a meta-analysis of methods that research studies show support student achievement, the following have significant effect sizes: identifying similarities and differences, summarizing and note taking, reinforcing effort and providing recognition, homework and practice, nonlinguistic representations, cooperative learning, setting goals and providing feedback, generating and testing hypotheses, and activating prior

knowledge. Some of these,, such as homework and practice and identifying similarities and differences can be incorporated into large lecture classes using technology such as on-line homework systems and “clicker” questions. Others seem to require at least some small group time, whether led by an instructor, a TA or peer teachers or learning assistants (Marzano, Gaddy, & Dean, 2000).

How change is communicated at all levels may be one of the most important factors in realigning goals from institution to faculty to students. In any model for general education, faculty input and orientation is important in shaping the curriculum. The importance of faculty input is highlighted by V.R. Smith and colleagues (2001) in a review of changes made to the Liberal Studies Program at James Madison University which ran into difficulty partly due to lack of clear communication and openness with the faculty about the need for the redesign and the direction it would take.

The JMU case was offered by the authors of the report as a case study of how not to proceed with reforms. The authors assert that difficulties will follow when the balance between disciplinary content and interdisciplinarity, and how the balance will be achieved, are not thoroughly examined in advance and a consensus reached. Among the strategies recommended to ensure a better reform process is the idea of assessing the old program before revision. General education assessment at JMU had been “essentially an unmapped frontier” and there was no clear picture of what students were getting from the original general education program. In JMU’s case meaningful assessment apparently did not result immediately after reforms due to a lack of coherence in course goals. This indicates that in spite of the reform effort, there are disconnects between institutional

goals and assessment of those goals (V.R. Smith et al., 2001, p. 97). In this case, the weak link seems to be curriculum, although the curriculum was designed to meet a large set of learning objectives. As with the Wright study, the lesson here is that it is important to know what faculty members think and how they see themselves in relation to institutional programs before embarking on major changes to curriculum.

The departmental structure of the College of Science at Mason could be an institutional barrier to reform. Reporting on curricular changes with general education as the focus in the current decade, Ratcliff (2004) points out that the quality of general education courses is strongly influenced by communication across departments. He points out that the forces of strategic planning, assessment and continual quality enhancement programs have made change an ongoing process. A danger Ratcliff warns of is a general education curriculum created by individual faculty members as single courses, a definite problem with general education continuity in universities with distribution models (2004).

Cost is a driving factor in limiting change. Many potential reforms require small sections or use of Teaching Assistants in lecture. General education science at Mason is primarily taught with large (often over 100 and up to 350) enrollment lecture sections combined with lab sections ranging from 20 to 30 students. A common reason cited for not implementing reforms is cost. Teaching assistants, used in large enrollment courses at some universities to allow more individualized assignments in lecture classes, add additional expense, and their role at Mason in science classes is generally confined to teaching labs and recitations.



Some solutions to the cost conundrum might be moving to a common core curriculum meaning that enrollments would be predictable (Gaff 1999, p. 7). Taking advantage of technology for delivering much of the lecture material might also be a solution that would help individualize instruction without costing more. (Gaff, 1999, p. 6)

Another cost of committing to improving general education science is the cost of training. Robert Shoenberg speaks of the difficulty of propagating goals when many general education classes are taught by graduate students and adjunct instructors or lecturers who have no long term connection to the university and usually receive little in the way of orientation and training (Shoenberg, 2005, p. 12).

## **Conclusion**

For many reasons science has been a part of general or liberal education for at least a century. While institutions outline goals for natural science courses in general education, there are many barriers inhibiting transmission of these goals to the students. With the idea in mind of trying to trace which, if any, general education science goals are understood and reached by students in the courses, I structured a series of interviews with instructors and focus groups with students to probe issues of alignment at George Mason University. The methodology follows in chapter 3, with an analysis of what I found in chapter 4, and some recommendations about the path Mason might take as it restructures general education in chapter 5.

## **CHAPTER 3: METHODOLOGY**

### **Purpose of the study**

As outlined in the introduction, it seems likely that, unless practice aligns with goals, students will not necessarily achieve what the university intends from general education science courses. I have structured my doctoral work to examine three strata that seem most critical in influencing outcomes: institutional goals, faculty practice and learner perceptions of value. Because I have been involved in many aspects of general education science, from institutional assessment of scientific reasoning to serving on a committee to restructure the general education science curriculum, the appropriate framework for this research is problem-based action science. The heart of the research is a case study of general education science at Mason. The case study addresses the question of alignment of goals at the university, and stands alone as a contribution to the literature on general education science. The findings from this case study should benefit Mason in the ongoing work of the science general education curriculum committee.

In the next sections, I will explain the rationale behind action science, the goals of problem-based research and the specific methodology, data collection process, and method of analysis.

### **Action Science**

Argyris et al. (1985) define action science as a “science of practice.” Roots of action science can be traced to John Dewey who deplored the separation of theory and

practice and advocated the reunification of knowing and doing (Dewey, 1929). Action science is a collection of approaches that allow the researcher to be an active participant in the process being studied (Lodico, Spaulding, and Voegtle, 2010). I have chosen to conduct the study of general education natural science from the “insider” point of view of someone at work in the field and actively involved in helping to shape the direction of change.

Action science uses methods of social science with a view to generating “knowledge that is useful, valid, descriptive of the world, and informative of how we might change it” (Herr & Anderson, 2005). It is used in institutional settings as a way to examine and act on issues that arise in the course of practice and has been popular in educational settings. It is not always published, nor is it always intended for general application. However, it can both add at some level to fundamental understanding of the educational process, and can serve as a source of information for practical decision-making (National Research Council, 2002, Shavelson and Town, 2002). An important difference between an applied research format and action research is the degree of participation of the researcher in the process of applying knowledge gained. The process of action science often involves a repeated set of cycles of data gathering, implementing a plan based on the data, observing effects of the action and returning to evaluate the effects then repeating the cycle (Herr & Anderson, 2005).

I have situated this dissertation in action research, partly because the process of change to the general education natural science program at Mason is ongoing, and will continue in cycles in the future if the history of general education is an indication. I hope

to continue to be involved in the process of assessment, innovation, and improvement in my role as a faculty member teaching general education science. Practically speaking it is necessary to find a stopping point for a dissertation however. As an endpoint for this project, I will discuss the process of developing a new set of goals for general education science up through May 2011, and will include developments since then in a short afterword.

Separate from the work of the committee on general education science, I have collected interviews and focus groups with faculty and students, and will present the results as a case study. The purpose of the study is to look for areas where goals of students, faculty and university are aligned and areas where there are disconnects that indicate that desired goals are not getting through to learners. The case study should be a useful source for the general education science committee as it continues to work to improve general education science at Mason. Insights I have gained in the process of reading and researching should help me contribute as a member of the general education natural science committee. Already I have had opportunities to contribute as we have discussed which goals need to be addressed by changes in the curriculum. The interview and focus group data should help us understand where goals are being met or failing to be met and may provide a model for continuing informal assessments to probe implementation of new goals. In addition, this study of alignment at Mason should have significance for other institutions with similar general education science structures as they respond to the challenge to prepare students for an increasingly complex society through science education for non-science majors.

**Problem-based methodology.** Problem-based methodology is a subset of action research. The focus of problem-based methodology is on researcher and practitioner dialogue to achieve desirable outcomes (Robinson, 1993). Rather than observing components of a practice from a distant viewpoint and attempting an objective and detached analysis, researchers in problem-based methodology engage with practitioners in order to understand the problems involved in practice and attempt to resolve them (Robinson, 1993). While it is not clear that understanding and resolving a particular problem of practice can easily be generalized beyond the case, it is nevertheless important to examine the case for components that are not completely case specific and might be replicated in other settings. In the problem under consideration here -how to know if science learning is occurring when it is questionable that institutional goals are being transmitted and received - analysis and solutions could be generalized to similar programs undergoing evaluation and change at similar institutions (Herr & Anderson, 2005). A process of looking at alignment and incorporating institutional goals as the curriculum is restructured would provide a route to continuous improvement as the school is asked to respond to questions about outcomes.

**Empowerment evaluation.** A valuable perspective as this process continues comes from empowerment evaluation. Empowerment evaluation uses trained program participants to evaluate and improve program practice. The cycle of evaluation includes the major elements shown in Figure 1. This simplistic rendering of a complex process should not be construed as a set of steps to follow, at any one time an institution or program may have ongoing efforts in all four stages and there will be overlap across

areas in the figure. My role in this process has been mostly concentrated in the taking stock area, considering perceptions of goals and values in the program, and in drawing out views of the program from faculty and student participants.

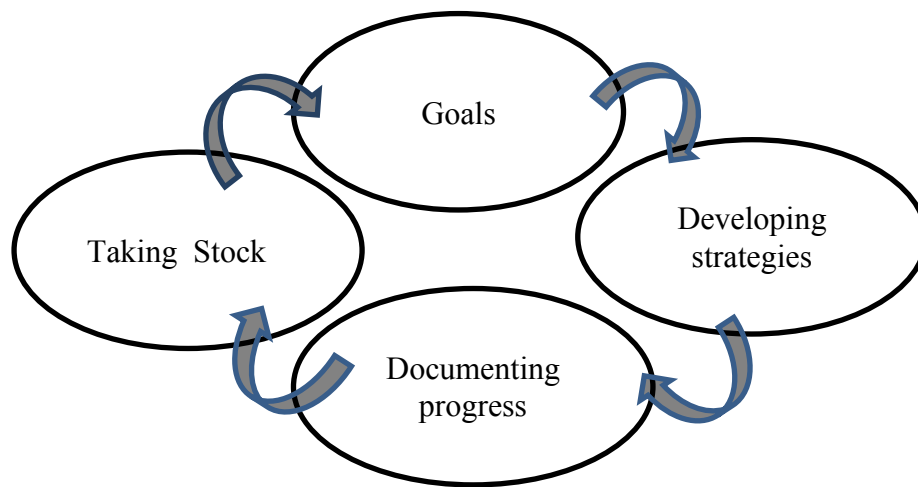


Figure 1: Cycle of empowerment evaluation

**Organizational problem-solving.** An important idea in problem-based learning is the theory of organizational problem solving (Argyris, et.al., 1985) and has to do with whether changes preserve the principles already in place (single loop learning), or allow the possibility of changes to values, goals and key assumptions (double loop learning) (Robinson, 1993, p 42). As of this writing, it appears that the general education science committee is committed to a process of change that challenges underlying principles and structures, and opens the door to a wide variety of possible formats for general education science with an underlying foundation of institutional goals. In this sense, it seems we are embarked on a double loop process, attempting to discover and evaluate underlying

values and assumptions (Argyris, 1999). Single loop learning would be a process of identifying a problem and taking some kind of action. Single loop learning may be satisfying to participants who may expect a single concentrated effort to result in long-term change, but it seems more likely that changes will come about only if the committee continues to return to core values as a lens for change.

**General education science restructure.** In the context of the Mason general education science curriculum restructure, two views emerged during nearly every discussion of the volunteer group trying to redefine goals. One view stressed changes within the existing system, looking for ways to increase student engagement and performance, but not questioning the utility and validity of the existing structure. The second view puts nearly everything on the table for discussion and potential change. My role in the group was as a voice from the instructional faculty and I contributed ideas and perspectives from the point of view of a practitioner. In addition, sources and knowledge I have gained during the course of research have helped me gain a broader perspective, which has enabled me to understand better the views of both groups. Ultimately, it is the committee as a whole that will have to decide between changing within the accepted current paradigm, or committing to deep-seated change, which probably cannot be accomplished without lengthy discussion, and refocusing, plus training if changes are adopted. My study of alignment may be useful as a tool to check and then improve alignment of goals and practice in either case.

## **The Case Study**

I have structured the research project as a case study investigating general education science alignment at one institution, George Mason University. Analyzing the process at one institution has two purposes, to understand alignment issues as the process of transforming general education science at Mason continues and to add to the literature on general education natural science teaching and learning. The case study has three layers, as I will outline in the following discussion.

“Core sample” is my metaphor for structure of general education at a specific institution. Meteorologists use core samples of glacier ice to find evidence of changes over time in Earth’s atmosphere. Geologists use drilled rock core samples to find evidence of processes at work in Earth’s past. As in these core samples, the object of study is a bounded system (Lodico, Spaulding, Voegtle, 2010) with well-defined boundaries. In the case of general education science at Mason, the wider boundaries are the general education science program at the university. Layers that contribute to the understanding of the system as a whole are instructors teaching general education science courses and students who have taken the courses while a brief survey of goal statements from other universities will help situate George Mason’s program in current institutional thinking patterns. The sample is limited in several ways. I limited the instructors to those who taught general education science lecture during the 2009-2010 school year and the students to those who had completed a natural science course for general education. Institutional goals for Mason include both the goals in use up until 2011 and the new set of goals developed during the Spring 2011 semester. I will discuss details of how the case study was conducted in the rest of this section on methodology and will discuss the



results and insights into general education science provided by the informants in the research chapter.

**Rationale for a qualitative study.** I deliberately chose a qualitative case study structure rather than a quantitative one. My argument is that such a sample, although it is not a representative statistical sample, gets at the flavor of the program. Individual instructors teach differently and have strongly held views about what they hope to accomplish in their classes. Interviews with them based on loosely structured questions should uncover their underling goals for instruction and their assumptions about purpose (Cohen, L., Manion, L. & Morrison, K., 2007). Similarly, students have definite ideas about the worth of individual courses and can talk about what they see as purpose and ultimate goals of these courses after they have completed them. Any commonalities in perceived goals even in this limited sample are significant, particularly when there is also alignment with institutional goals. Finding divergence could also be useful as it could provide new ways of getting at the problem of value and purpose of science courses for non-science majors and could help the university chart future directions for the program. A brief overview of Mason as an institution, a discussion of goals at Mason as of 2011, and a more detailed discussion of phases of the case study follow.

**Institutional setting.** It is important when designing curriculum to think about institutional character and to set goals and design programs that will fit with the large mission of the institution. It is not likely that all institutions will share a common set of goals for general education, nor is it clear that such a common set of desired outcomes would be desirable (National Research Council, 2002). Natural science covers a

tremendous range of disciplines all with different desired learning outcomes and different points of intersection with students as developed citizens of a democracy. While there is much to be learned from how other institutions structure programs, in the end a program must be embedded in institutional culture and reflect institutional values (Rhodes, 2010). George Mason is a public university, originally part of the University of Virginia system. A relatively new campus, it received independent university status in 1972 (George Mason University, n.d.) and had expanded to its current population of just over 20,000 undergraduates by the fall of 2011. A guiding motto for the institution is “Where innovation is tradition.”

Innovation inspired an attempt to reform general education in the 1980s. The school initiated a trial general education program, the Program for Alternative General Education (PAGE), in 1983. In 1997, PAGE evolved into New Century College and an honors program, now an Honors College. Currently, general education courses, including natural science, are offered through a distribution system, the most common arrangement at universities today (Hart Research Associates, 2009). Most undergraduates at George Mason University are required to take seven or eight credits of laboratory science, with Biology, Geology, and Astronomy among the most popular offerings. For the most part the courses that meet the requirement are offered in large lecture format, with smaller laboratory sections taught by teaching assistants or contingent faculty.

**George Mason University goals.** Goal statements for Mason through Spring, 2011 are drawn from three sources, the broader philosophy of general education at Mason

(George Mason University Provost's Office, 2011), specific learning goals for natural science (George Mason University Provost's Office, 2010), and the scientific reasoning outcomes developed by Mason science faculty members in conjunction with the Office of Institutional Assessment at Mason, prior to the implementation of a new general education curriculum in 2001. All three documents are included in the Appendix A and I will give an overview of their contents when I describe research results in Chapter 4. A new set of science goals, developed and approved by the general education committee in Fall 2011 (also in Appendix A) have now replaced these goals, and while this study used the goals in place prior to Fall 2011 as the baseline for looking at alignment, I will also consider the current goals as I look at faculty and student perceptions about natural science courses.

The scientific reasoning goals are important for this study because they were developed by science faculty and are intended to provide a platform for evaluation of the program for both external review and program improvement. Because they were not “imposed from above” but came out of lengthy meetings and discussions with faculty from a broad range of science departments they should reflect what faculty consider important.

As a participant in a group of faculty developing an assessment to test the Mason scientific reasoning goals, I became interested in the problem of testing a universal set of outcomes using courses that represented such a range of content. Few of the scientific reasoning goals were universally accepted as foundational for individual science disciplines by the faculty members who developed the assessment. Mapping is a key skill

in geology, for example, but is not addressed at all in a typical general education biology course. Error analysis is an important part of introductory physics lab courses, but introductory astronomy lab courses deal with it only in passing. Discussion about processes and desired skills and learning outcomes in individual courses meant that developing the assessment also served as a tool for examining the goals for general education science. Members of the group were forced to examine their values about what mattered in teaching general education science. Many of those involved in developing the assessment are part of the group that first revised the goal statements in 2011 and is currently considering the best way to implement them across all the general education science courses.

**Data collection methods.** To get at issues of alignment of goals and outcomes at Mason, I have used three tools from qualitative research as follows: Phase 1: For a wider picture of what colleges and universities expect of general education science I reviewed web documents from a somewhat random selection of schools. Phase 2: To understand the thinking of professors teaching general education science at George Mason I interviewed a small sample of teachers. Phase 3: Finally, I conducted focus groups with students who had completed their general education science courses. I designed the interview and focus group questions, organized goals data with Mason's own goal statements in mind, and submitted the plan to the university Human Subjects Review Board for approval. The next sections detail choices made and the rationale and validity for each of the research components.

**Phase 1: Institutional goals for general education science.** The purpose of this part of the study was to explore the character and structure of general education science within general education programs at 14 other institutions as a kind of “ruler” to measure the program at Mason. A study commissioned by AAC&U found that 71% of participating AAC&U institutions included science as one of the knowledge areas addressed by the institutions common set of learning goals (Hart Research Associates, 2009), so I was confident that I would find goal statements for natural science at most institutions.

Newton (2000) identifies three broad patterns of general education at various schools: great books, scholarly discipline, and effective citizen. Although he does not break down general education into component parts to examine, for example, how science or history or writing are dealt with in each one, his overview of approaches makes it possible to infer what science might look like in each model. Table 3.1 is based on the models outlined by Newton with possibilities for how science might be treated in each.

Table 1: Approach to science in three major models of general education (adapted from Newton, 2000)

	Great Books	Scholarly Discipline	Effective Citizen
Focus	“Big questions” classical and historical emphasis	Disciplinary focus – deep understanding of subject	Life skills and community needs – Educating for citizenship
Science role	Study science processes in historical context	In depth content and concepts of particular science disciplines	Understand and evaluate science processes and claims in context of current culture
Instructor’s role	Teach in collaboration with instructors from other disciplines emphasis on connections	Teach within field, may be coordinated by research scientists in discipline	Teach either in or out of discipline - processes and implication of science stressed.
Goals for Non-majors	Depth - understanding of roots and tradition of scientific discovery	Deep introductory level understanding of a science discipline	Understanding to evaluate and understand science in daily life.
Course structure	Readings from classical and contemporary authors - big ideas and movements in science	Disciplinary –usually textbook based	Reading contemporary sources as starting point for science investigation
Associations –sources of curricular materials	The Association for Core Texts and Courses <a href="http://www.coretexts.org/index.htm">http://www.coretexts.org/index.htm</a>	Project Kaleidoscope <a href="http://www.pkal.org/documents/PhaseVIFILProjectBackground.cfm">http://www.pkal.org/documents/PhaseVIFILProjectBackground.cfm</a>	Sencer –Science Education and Civic Engagement <a href="http://www.sencer.net/">http://www.sencer.net/</a>

Based on the models in Table 1: Approach to science in three major models of general education (adapted from Newton, 2000), I determined basic “who, what, why, where, when, and how many?” questions to analyze general education plans for science

at selected institutions. From the original list, I distilled the following five questions to use as a foundation for organizing the data in preliminary stages of investigation.

1. What are specific stated goals for the program? This included both broad goals for general education and, where available, specific goals for science.
2. What kind of general education program model does the science portion belong to: menu driven, core requirement, or something else?
3. Where in the organizational structure do the courses fit: specific science departments, general education department, university wide core requirement, or some other arrangement?
4. Does content meet general education requirements only or do the courses that meet the requirement also serve as introductory courses in the major?
5. What are specific credit hour requirements and how are those hours broken down in terms of lab and lecture?

Since I wanted to get a picture of how most institutions structure general education science, as well as a sense of interesting arrangements outside of the mainstream, I selected institutions of various types and sizes and with different approaches to general education. I used guides published on college and university web sites as the source of data about the structure, goals, type of program, etc. for a number of schools of various types.

To choose institutions, I began with Carnegie classifications to select several institutions that seemed similar to Mason. I also examined general education science structure at Virginia Universities, as well as Northern Virginia Community College, a source of transfer students for Mason. Other schools are included in the study because they turned up in readings about the history and background of general education in the U.S., were ones I knew from my own experience, or were suggested by others interested

in the topic, or had programs of interest because of revamping programs or some other reason.

Because most institutions have more than one way of delivering general education courses including science, (Hart Research Associates, 2009), I focused attention on general education for the main body of students and did not analyze learning communities or honors programs.

Once I had collected the information, I categorized each program by type of goals, position of general education science courses within the institution, whether courses were designed for both general education and science majors, etc. and examined them for commonalities and interesting differences. In particular, I looked for goals that either matched Mason's or were substantially different. In some cases, it was difficult to interpret exactly what was meant by terminology such as "nature of science" or "relationship of science to society." In those cases, I looked in more depth at course offerings with the assumption that courses were included in the general education science curriculum because they reflected institutional goals. I wrote a brief synopsis of the program at the particular institution, and finally summarized findings in various goals categories.

**Phase II: Faculty interviews.** I used semi-structured interviews to get a sense of what faculty teaching general education science courses saw as the purpose of their courses and their understanding of the published goals of the University for general education science. I chose semi-structured interviews to give a common broad structure



to each interview while allowing flexibility when warranted by faculty responses (Lodico, Spaulding & Voegtle, 2010, p. 24).

To select potential interview subjects I made a list of faculty members who taught courses that satisfy natural science requirements, and then assigned a random number to each instructor and began requesting interviews via email (see appendix B for the relevant protocol and a copy of the emailed request). I sent a second email to faculty members who did not respond to the first email. When faculty members responded positively to the interview request, I set up a time and place and tape-recorded interviews ranging from about 40 to 50 minutes. Each faculty member was assigned a constellation name as a pseudonym. At the start of the interview session, I gave each faculty member a short survey intended to find out the length of time they had taught the course and their rank at the university. Chapter 4 includes a table summarizing demographic data for the science faculty members who were interviewed.

During the interview, faculty members were given copies of the general education statements “Life, Liberty and the Pursuit of Happiness,” scientific reasoning outcomes, and the short goals statement for general education natural science (see Appendix A for all of these) to review and were offered the opportunity to suggest additions or modifications they would make to the university statements. After each interview, I listened to the recordings, made written notes outlining the broad topics of discussion, then wrote a short narrative for each interview. In particular, I noted times during the interview that were particularly relevant to the question of alignment of practice with

Mason goals for general education. In addition, I compiled a list of faculty suggestions and ideas for general education science.

**Phase III: Student focus groups.** Because I felt that one on one interviews might intimidate students, I chose instead to set up focus groups with 2 – 6 students. Lodico et. al. recommend groups of 7-10 for optimal interaction (2010, p. 123) but also caution against groups that are too diverse. Since I intended to interview students who had taken a wide range of general education science courses and would have a variety of majors, I aimed for an ideal size of five. The actual focus groups had two or three participants. This turned out to be ideal since students seemed to relax quickly, listened to each other, but could respond individually and in depth. As with faculty, I assigned a code name, in this case a name that began with the same letter as the student's reported major. Each student completed a short demographic survey at the start of the interview. Results are summarized in Chapter 4.

A difficulty with the focus groups turned out to be recruitment. I offered a small incentive, a \$15 gift certificate at the campus bookstore as part of the protocol. After several unsuccessful attempts to recruit participants, I reformatted the announcement to allow students to pull off a tab with my contact information and used a larger font to emphasize the incentive. I posted the announcement on campus at student centers and on classroom building bulletin boards and got a number of responses. The announcement and protocol are included in the appendix along with focus group questions.

I conducted the focus groups in the faculty meeting space in the Physics department or in my office and supplied light snacks in addition to the gift cards which

were distributed at the end of the approximately hour long focus group meeting. I tape-recorded these groups and, as with faculty interviews, listened to them again to find areas of alignment and disconnect. Students were given university goal statements and asked during the session whether they remembered any of the stated goals being taught either explicitly or implicitly in their classes. As with faculty members, students were given an opportunity at the end of the interview to make suggestions about the goals and were encouraged to talk about how they thought these classes might benefit them in the future.

As with the faculty interviews, I listened to the recordings, made written notes, and combed through them the focus group recordings for words and phrases matching or roughly synonymous with the general education goals, of both Mason and other university goal statements. Summaries of each focus group meeting are located in Chapter 4. Ideas that might have value in reconsidering general education science are included in the recommendations chapter.

## **Analysis**

I began the analysis of data by summarizing results for each of the individual parts of the Mason case study that seem to most impact alignment of goals from institution through courses to students. As pointed out in the *User-Friendly Handbook for Mixed Method Evaluations* (Frechtling, J. & Sharp, L. eds., 1997), analyzing quantitative data involves sifting through data again and again, looking for patterns and themes. In a process I followed with all the data sources, I began by sorting through the institutional goals looking for broad types of goals, such as content goals, broadening of perspectives goals, and critical thinking goals. In the case of institutional goals, once I

defined categories I assigned elements of the goal statements for each institution to the appropriate category and displayed the results in a table.

Problems in this analysis are mostly those of interpretation, trying to sort out what the writers of the goals had in mind since the language varies from institution to institution. I have included some of criteria I used to make the assignment in the results summary at the end of the institutional goals section.

For the interview data, I looked for direct statements that relate to the research questions. For example, instructors were asked directly if they had seen the goal statements, and if so, where. Since none of the faculty members was familiar with the institutional goals in more than a very superficial way, I went through each interview to find indicators of what the instructors considered goals and learning outcomes for their students and compiled them in the results section. I divided the goals into two categories, those that match Mason's stated goals for general education science and those that went beyond the institutional goals. A third item of interest was suggestions from the faculty members about changes and improvement to general education science. These three things are included in the results for faculty interviews.

Student focus groups got the same treatment. I sorted through interview transcripts looking for goals the students believed were addressed in the course, those they thought should be addressed, and ideas for changes to general education science.

These summaries form the base for Chapter 5: Conclusion and Recommendations. In that chapter, I look again at the original research questions and outline my findings. Based on that I have made some recommendations compiled from both what I have found

about alignment issues and what the three layers of the case study revealed about possible directions for Mason as we continue to revise the general education natural science program.

### **Validity and Reliability**

Questions of validity in action research relate to the goals of the research. If a goal of the research project is the achievement of action-oriented outcomes, a validity test is the extent to which actions occur that lead to resolution of the problem (Herr & Anderson, 2005). The idea of workable solutions as evidence of validity again is rooted in Deweyan philosophy with its emphasis on pragmatism. As stated in the National Research Council document on scientific research in education (2002), considerations of validity must be balanced with credibility of the researcher and relevance of the work to practice. In this case, it is imperative that I make every effort to view the data collected from interviews and focus groups as objectively as possible, acknowledge my own biases and pre-conceptions, and look for patterns and deviations from patterns with detachment.

The case study part of the dissertation can be evaluated on its own merits as part of the mainstream of social science research (Patton, 2002). It is important to stress that as an involved participant I am vulnerable to bias, but also important to understand that, as Fetterman (1996) points out, self-evaluation by insiders can be a powerful tool in an organization. Those on the inside are knowledgeable about processes and practices in ways that those outside the organization may not be. Critical reflection by insiders about processes and practices, followed by objective approaches to finding differences between goals developed for the organization and measurable outcomes helps provide internal

validity. Using method triangulation, by including, for example, interviews with instructors and examination of syllabi, and source triangulation through multiple interviews and focus groups, is a valuable way to step outside my own point of view to see these courses as others see them (Patten, 2002, p. 556).

Beyond the question of bias, my hope is that data collected in this project will be useful in the short term as a check on whether goals are being met, but also in the long term as a baseline for an ongoing evaluation process that could be repeated and extended by general education science faculty, always with the question in mind “Is our program doing what we want it to do?” It is important to realize that change may come incrementally and may involve more than assessing immediate perceived value. In essence, this dissertation is a way of sampling where Mason is currently, and making recommendations about potentially productive directions in the areas “...training, facilitation, advocacy, illumination, and liberation” as suggested by Fetterman (p. 9).

**Validity.** In order to get as complete a picture as possible of the relationship of goals and outcomes for general education natural science at Mason, I have used various measures, including interviews, focus groups, and document review (primarily of publically available documents on the world-wide web). The varying points of view on the same issue, that is alignment or lack of alignment of understanding of goals for general education natural science, provide triangulation, an important part of the claim of validity for this study (Patton, 2002, p.93). My purpose here is to get a sense of how faculty and student participants in the general education program at Mason address, and

react to, institutional goals for general education science, and how these institutional goals align with those of other higher education institutions.

Filstead (as cited in Patton, 2002) states “it is crucial for validity, and consequently, for reliability – to try to picture the empirical social world as it actually exists to those under investigation, rather than as the researcher imagines it to be.” It is a constant process of evaluating statements from the point of view of, not what I read into them, but of what the person seems to be intending.

I have attempted during interviews and focus groups to understand and probe the positions of those being interviewed to understand their points of view as completely as possible while holding my own views at arm’s length. The idea of looking for data that support alternative explanations as articulated by Patton (2002) is a helpful way to uncover patterns that would not otherwise be obvious. The validity of the case study depends on the quality and objectivity of observations and explorations of how the observations support or fail to support the assumption that goals for general education science are aligned at GM.

In light of Mason’s mandate to assess scientific reasoning, one measure of validity would be whether increasing alignment in goals also enables the institution to design an assessment that functions across the curriculum for general education science. Such a validity test is not practical currently as the process of change is still in early stages, but will be a further test of whether goals and practice are aligned at Mason.

**Reliability.** In this study reliability has to do not with repeatability, but with the idea that a similar process that collected similar data would come to similar conclusions.

The foundational question at the heart of this study is:

If a consistent underlying structure could be formulated and implemented in general education science courses, with course content built on the structure but remaining flexible and dynamic, would goals be transmitted from institution to instructors and through courses to students?

By looking at goals and whether or not all or any of them are being transmitted and understood by instructors and students, we can in the future return to the question of the underlying structure and whether it supports the transmission of goals I theorize that we can deduce something about the underlying structure that supports the transmission of goals. If the answer to the question of whether goals are being transmitted and received is an unequivocal “yes”, then the next step in investigation is to study whether that transmission is robust even when goals are changed. If, as I suspect, transmission of the goals to those who implement them does not happen to any great extent, then new goal statements may not be enough, and those involved in general education will need to concentrate building a structure that will sustain transmission even as goals change with changing needs and institutional perspective.

The subject of this study, evaluating whether goals are or are not understood, implemented and received, can be evaluated on its own merits, but also on whether understanding of this part of the process is valuable in further stages of evaluation and restructuring of the program. At Mason the general education natural science group is



already embarked on the next stage, implementing goals that take into account the needs and outlook of the institution, the teaching faculty, and, to some degree, the students.

But if the original goals are not effectively transmitted, a more developed structure for general education natural science, perhaps including instructor training, instructor-led formative evaluation, and interviews with students about their course experience, might be considered to improve alignment. Goals assessed at the level of the institution would be a check on whether such structural changes are having an effect. Over time the strength the structure could be strengthened, as individual courses are designed with the desired outcomes at the center, rather than at the periphery.

**External validity.** Alternative hypotheses for either alignment or lack of alignment of understanding of goals are possible. Goals could align from institution to the level of course and instructor because science faculty, under the auspices of the general education curriculum committee, suggested and implemented them. Developing goals statements may involve only a small number of faculty, but it is possible that these faculty members reflect goals transmitted to science faculty as students. In other words, they may come from a common and generally accepted cultural basis for scientists..

At the faculty level, lack of alignment might come not from lack of a robust underlying structure for general education, but because faculty members claim academic freedom and teach what they see fit rather than what the institution has put in place for learning goals. If so, learning goals mentioned by faculty might diverge widely.

Alternative hypotheses arise at the student level too. It could be that students are disengaged and learning in superficial ways and not at all attuned to goals that underlie

the content of the course. Perhaps students are unprepared and not ready to learn and understand, or do not read or come to class and have missed any teaching directed at goals that is not presently directly in the textbook or on instructor's slides. Or perhaps students have been exposed in a meaningful way to university goals for general education natural science, but haven't yet incorporated them into their thinking patterns and will see how the pieces fit together only after graduation and experience in the work world.

Another alternative hypothesis is that the original goals statements are vague and open to interpretation, or perhaps removed from the realities of science disciplines, making it difficult, if not impossible, to include them in natural science classes.

**Potential sources of bias.** Because improving general education science courses was a driving force that impelled me into the Doctor of Arts program in Higher Education, the topic is a natural fit. However, the fact that I am immersed in general education science as instructor and participant in the redesign effort raises the question of bias. Bias enters in first simply in the choice of topic. Improving general education implies that something needs to change, and that, of course, is exactly my view. However, during the course of the work I have been surprised both by the possibilities for positive change that interviews and focus groups have revealed and the need to retain what is currently working based on the dangers inherent in sudden and comprehensive change. Herr et al. (2005) warn about the dangers of action research, especially when done by an insider practitioner who may be unduly influenced by the culture in which the practitioner/researcher is immersed. Since I came to the study with a strong bias toward transformative change, it is possible that the surrounding culture is a moderating

influence and has, over the course of the investigation, moved my views back toward the maintenance of the status quo (Argyris, 1999). One of the “potholes” along the road to general education reform is trying to do too much too fast and risk doing nothing at all, (Gaston and Gaff, 2009) so the tendency to lean toward the status quo experienced by an insider researcher may be a good thing in this case. On the other hand, the risk involved in advocating innovative change might inhibit real double loop learning on my part. In the end this might be a strength of action research, I stand both inside and outside of the process and have made an effort to evaluate both immediate and long-term consequences of change.

**Timing of the study.** To write about an on-going process is a challenge for an action research. Where do I step into the flow of personal and institutional change in general education? When do I stop and close this report for writing purposes? The starting point for this investigation is a bit fuzzy since I had been involved in issues involving general education science for a long time before this study began. The official beginning of my part of the project was with a successful dissertation proposal in July of 2009, followed by HSRB approval of a protocol for interview and focus groups in December 2009. I limited the choice of instructors to interview to those teaching during the 2009-2010 school year, and carried out research during the period 2009- 2011.

I chose the ending date of August 2011 because it is necessary to stop somewhere and because it marked the end of the first round of general education science reform. By September 2011, a new set of general education science goals had been submitted to, approved by the College of Science faculty, and approved by the general education

committee of the University. While changes to courses had not been implemented at the time of this writing an update on what has happened since the end of the spring 2011 semester is included in Chapter 6.

## CHAPTER 4: RESEARCH

### Introduction

In this section, I first summarize institutional goal statements and learning outcomes, then present summaries of individual faculty interviews and focus groups, and finally put the case together in a summary of findings.

In the section for institutional goals, two tables give a brief overview of findings, while more detailed information about the program at each institution is in the intervening text. Table 2 lists institutions sampled, their Carnegie classification, and the structure of the general education. Another column pinpoints the place where general education science at the institution is administered, whether courses are developed and administered in science departments, in a general education department or somewhere else. Finally, I have included the reason for selecting each institution. Table 3 offers paraphrases of goal statements for natural science at each institution. In most cases, I have condensed statements and sometimes combined elements in order to make comparison with Mason's goals more straightforward. The text summaries of the general education natural science program for each institution include an overview of the general education program and goals when it was available on the website, and detailed descriptions of some of the science offerings. While many universities have multiple routes to general education, my focus here is primarily on general education natural science for the bulk of non-science majors at the institution.

Basic information about the participants in faculty interviews and student focus groups is summarized in Table 4 and Table 5. Following the tables in each section, I have included narratives outlining results of each faculty interview and student focus groups. In all cases, I emailed the question list to participants ahead of time and gave them a copy during the interview or focus group. I have included the interview and focus group starting questions in the appendices. Because these sessions were loosely structured, I often asked follow-on questions that differed for different groups and interview subjects, though the main thrust of each session was the same, looking for areas where Mason goals for general education natural science were either being met or not, and gathering as much specific information as I could about how the participants understood the purposes of the courses. In addition, I gathered participant ideas about what they saw as appropriate goals of the program, and how courses could be restructured to make them more valuable for learning.

Following the goals, interview and focus group summaries, the section titled “Findings” is an attempt to pull the data into a coherent view of alignment of goals at Mason. This section will include what I observed and how it relates to the thesis that institutional goals are either not transmitted to students, or not fully understood. Finally, I will also collect ideas gathered from faculty and student participants, many of whom had creative and potentially valuable ideas about improving learning in general education science. Some of these ideas might be useful when considering the direction of change for either general education natural science goals at Mason, or potential course structures that would help meet the goals.

**Institutional goals survey**

The following table summarizes Carnegie type, structure, and location of the general education program as well as the reason the school was chosen for this survey of general education natural science goals. Information on Type comes from the Carnegie Foundation for the Advancement of Teaching website's look-up function (<http://classifications.carnegiefoundation.org/lookuplistings/institution.php>).

Information about general education type and administration is drawn from institutional webpages, which are referenced in the following text describing each institution.

Table 2: Institutions surveyed

School	Type	General education model	General education science administration location	Reason for choice
George Mason University	Public RU/H <sup>2</sup>	Distribution	Departmental	Institution under study
Macalester College	Private – not for profit Bac/A&S <sup>3</sup>	First year + distribution	Departmental	Alma mater
University of Hawaii-Manoa	Public RU/VH <sup>4</sup>	Distribution	Departmental	Strong astronomy program
University of Kentucky	Public RU/VH	Core competencies with selection from a range of courses	Departmental	Program has been revamped recently with a strong emphasis on assessment
Carleton College	Private – not for profit Bac/A&S	Distribution	Departmental	Liberal arts
Michigan State University	Public RU/VH	Core – Integrative studies	Center for Integrative Studies in General Science	SCHEV peer institution Assessment information available
University of Colorado – Boulder	Public RU/VH	Named core but appears to be distribution	Departmental	Uses learning assistants in some science programs

<sup>2</sup> Research Universities (High research activity)<sup>3</sup> Baccalareate/Arts and Sciences<sup>4</sup> Research University/Very High research activity



James Madison University	Public Master's L <sup>5</sup>	Core curriculum	Departmental	Virginia Institution
Columbia University	Private – not for profit RU/VH	Core curriculum	Frontiers of science university wide. Remaining 2 courses departmental	Unique program
Arizona State University (Tempe)	Public RU/VH	8 hours distribution, 4 hours designated quantitative natural science	Departmental	SCHEV peer institution
Cloud Community College	Public 2 year Assoc/Pub-R-M <sup>6</sup>	Distribution	Departmental	Assessment program
Virginia Tech	Public RU/VH	Distribution	Departmental	Virginia Institution
Old Dominion University	Public RU/H	Distribution	Departmental	Virginia Institution
Virginia Commonwealth University	Public RU/VH	Distribution	Departmental	Virginia institution
Northern Virginia Community College	Public 2 year Assoc/Pub-S-MC <sup>7</sup>	Distribution	Departmental	Articulation agreement – primary source of Mason transfers

<sup>5</sup> Master's colleges and universities (larger programs)

<sup>6</sup> Associate's--Public Rural-serving Medium

<sup>7</sup> Associate's--Public Suburban-serving Multicampus

**George Mason University.** The school under study is a large state research university in Virginia. Details about the college and its programs are outlined in the Case Study section of chapter 3 in the subsection “Institutional Setting.”

The core statement for general education “Life, Liberty and the Pursuit of Happiness,” is an overview of the goals of general (or liberal) education at the school. In short, students should develop the ability to continue to learn (life), develop patterns of thought free from prejudice and ignorance (liberty), and develop the satisfaction that comes from a more engaged and fulfilled life as they put ideals into action (pursuit of happiness).

Most students select general education courses from a broad range across science disciplines. Required courses come from a set of foundation requirements: written and oral communication, quantitative reasoning, information technology and ethics and core requirements: literature, arts, natural science, western civilization/world history, global understanding, social and behavioral science, as well as a one course synthesis requirement and a writing-intensive course in the major.

Courses that meet the natural sciences requirement included some 3-credit, nonlab courses such as “Foundations of Cosmological Thought”, “Introduction to Organic, Biochemical, Pharmacological, and Fuel Chemistry,” “Weather, Climate and Society,” “Environment and You: Issues for the Twenty-First Century,” and “Great Ideas in Science.”

Four credit lab science courses that meet the requirement include “Introductory Astronomy: The Solar System,” “Cell Structure and Function,” Chemical Science in a

Modern Society,” “The Ecosphere: An Introduction to Environmental Science I and II,” “Physics and Everyday Phenomena I and II,” and “Introductory Geology I and II.”

General education natural science courses that were named by students or taught by faculty in this study are outlined briefly in Table 6: Courses taken by students in focus groups.

Specific natural science goals up until 2011 included the following statement:

**Natural science goal:** Courses provide an understanding of natural science by addressing the critical approach of the scientific method, relation of theory and experiment, use of quantitative and qualitative information, and development and elaboration of major ideas in science.

Required: Two approved science courses. At least one course will include laboratory experience.

([http://catalog.gmu.edu/preview\\_program.php?catoid=5&poid=1437](http://catalog.gmu.edu/preview_program.php?catoid=5&poid=1437)).

The specific outcomes listed on the Mason institutional assessment page were:

- Students will demonstrate that they understand the ways of scientific knowing, including inductive and deductive, empirical and theoretical.
- Students will demonstrate the ability to develop and test a hypothesis. Students will demonstrate the ability to read and interpret data.
- Students will demonstrate the ability to interpret both primary and secondary sources.
- Students will demonstrate their knowledge of both quantitative and qualitative methods.
- Students will demonstrate an awareness of both the power of the scientific process and its limitations.
- Students will demonstrate an awareness of communication as an integral part of the scientific way of knowing, both between and among scientists, and between scientists and the rest of society.
- Students will demonstrate the ability to understand and value the role of science in both personal and public/societal decision-making.

\* *Revised in spring 2008.* (<https://assessment.gmu.edu/Genedassessment/outcomes.cfm>).

A committee to revise goals for general education natural science met in late December 2010 and continued through January 2012. In fall 2011 a new goal statement

was accepted by College of Science faculty and the general education committee. While the new goals were built on previous ones, the approach of the new statement is to emphasize student participating in inquiry and includes “foster curiosity” and “enhance enthusiasm,” affective goals that were not included prior to 2011. The revised goals for Mason general education science effective Fall 2011 are as follows:

The general education natural sciences courses engage students in scientific exploration; foster their curiosity; enhance their enthusiasm for science; and enable them to apply scientific knowledge and reasoning to personal, professional and public decision-making.

To achieve these goals, students will:

1. Understand how scientific inquiry is based on investigation of evidence from the natural world, and that scientific knowledge and understanding:
  - evolves based on new evidence
  - differs from personal and cultural beliefs
2. Recognize the scope and limits of science.
3. Recognize and articulate the relationship between the natural sciences and society and the application of science to societal challenges (e.g., health, conservation, sustainability, energy, natural disasters, etc.).
4. Evaluate scientific information (e.g., distinguish primary and secondary sources, assess credibility and validity of information).
5. Participate in scientific inquiry and communicate the elements of the process, including:
  - Making careful and systematic observations
  - Developing and testing a hypothesis
  - Analyzing evidence
  - Interpreting results

NB: Lab courses must meet all five of the above learning outcomes. Non-lab courses must meet learning outcomes one through four.

**Macalester College.** A small (about 2000 students) liberal arts school in St. Paul, Minnesota, Macalester’s mission statement reads:

“Macalester is committed to being a preeminent liberal arts college with an educational program known for its high standards for scholarship and its special emphasis on internationalism, multiculturalism, and service to society.” (<http://www.macalester.edu/academic/catalog/mhra1.html>)

A few key phrases in the college’s statement of purpose and belief include the idea of education as a transforming experience, the idea of intellectual growth, and broad understanding of the liberal arts. The second paragraph of the statement reads:

“Students should follow a primary course of study in order to acquire an understanding of disciplinary theory and methodology; they should be able to apply their understanding of theories to address problems in the larger community. Students should develop the ability to use information and communication resources effectively, be adept at critical, analytical and logical thinking, and express themselves well in both oral and written forms. Finally, students should be prepared to take responsibility for their personal, social and intellectual choices.” (<http://www.macalester.edu/academic/catalog/mhra2.html>).

Macalester currently has a “first year studies” program in addition to a distribution requirement. Several science seminars are electives in the first year studies choices, but all the first year studies seminars are intended to help students figure out what a liberal arts education is about, practice college-level writing and research and develop a relationship with the faculty member teaching the course. In addition to the first year seminars, students must meet an 8-semester hour Quantitative Thinking requirement. Students can choose courses in biology, chemistry, geology, mathematics, and computer science, or physics and astronomy, though a few courses in other departments also meet the requirements. These courses cannot be filled with AP, IB or GCE A-Level exams. The Catalog statement from the most recent revision in 2005, states that quantitative thinking is essential to liberal education, and that critical thinking skills

from these courses can carry over and reinforce critical thinking in other fields. There is an emphasis on breadth to allow students to be active participants in many facets of society.

Some of the specific skills vital to informed citizenry are measurement, estimation, and data analysis, in addition to asking and answering questions using quantitative tools, while recognizing when such tools are not appropriate. The college invites faculty from a variety of departments to teach courses involving quantitative thinking, though the majority of the acceptable courses appear to be in math and science.

In some departments, the general education requirement can be met with topics courses, but typically, it appears that courses are offered as both introductory majors' courses and general education courses.

The first year seminar courses with a science theme include “The Heart and Soul of Biology”, “Aids, Influenza & Malaria: Ancient Pathogens in a Brave New World”, “General Chemistry I and Lab –Structure and Equilibrium”, “Climate and Society”, “Dynamic Earth and Global Change”, and “The Science of Renewable Energy.”  
(<http://www.macalester.edu/orientation/courseregistration/firstyearcourses/>)

**University of Hawaii – Manoa.** This 100-year-old land grant university on the island of Oahu has unique programs that stem from its geographic location. The Chancellor’s Message for the school points out that its location in the Pacific opens opportunities for cultural and research diversity (<http://www.catalog.hawaii.edu/about-uh/chancellor.htm>). The school is similar to Mason in that it is a large (approximately 14,000 undergraduates) university, but differs in that it is mainly non-residential. Course

offerings reflect research interests of the faculty and the geographical surroundings of the University. General education is primarily organized as a distribution requirement, although students must also take three core courses in written communication, symbolic reasoning, and global and multicultural perspectives.

The relevant general education goal for natural science, which comes under the “diversification” heading in the general education program, is that students “...know the aims and methods of science” (<http://www.catalog.hawaii.edu/corerequirements/core-req.htm>). Students need three credits each of biological and physical science and a lab.

A few of the courses that meet the biology requirement are “Biology and Society,” “Hawaiian Environmental science,” “The Atoll,” “Sex differences in the Life Cycle,” and “Psychoactive Drug Plants.” Courses for science majors that satisfy the general education requirement have more traditional titles such as “Introduction to Biology.” (<http://www.catalog.hawaii.edu/courses/departments/biol.htm>).

The choices for physical science are primarily traditional introductory survey courses, but students can also choose from topics like archeoastronomy, astrobiology, and cosmology (<http://www.catalog.hawaii.edu/courses/departments/astr.htm>).

Oceanography offers “Global Environmental challenges,” “Science of the Sea,” and “Aquatic Pollution” to meet the physical science requirement and “Living resources of the sea” and “Aquaculture production” to satisfy the biology requirement. It appears that a series of topic courses mostly at the 100 and 200 level are offered in these departments to meet the needs of the general education population while a series of traditional surveys meet general education requirements for majors in the science.

**University of Kentucky.** The University of Kentucky is a 26,000-student university selected because it began a new UK Core for general education in Fall 2011, after piloting 60 courses in 2010 to meet new standards. It also includes some of its assessment criteria and rubrics online.

The new curriculum has four areas of concentration, intellectual inquiry, communication skills, quantitative reasoning, and citizenship skills ([http://www.uky.edu/GenEd/Documents/Learn\\_Outcomes.pdf](http://www.uky.edu/GenEd/Documents/Learn_Outcomes.pdf)).

Sciences are included in the intellectual inquiry concentration area. Goals of this concentration are:

- Students will be able to identify multiple dimensions of a good question (i.e., interesting, analytical, problematic, complex, important, genuine, researchable);
- determine when additional information is needed, find credible information efficiently using a variety of reference sources, and judge the quality of information as informed by rigorously developed evidence;
- explore multiple and complex answers to questions/issues/problems within and across the four broad knowledge areas: arts and creativity, humanities, social and behavioral sciences, and natural/physical/mathematical sciences;
- evaluate theses and conclusions in light of credible evidence;
- explore the ethical implications of differing approaches, methodologies or conclusions;
- and develop potential solutions to problems based on sound evidence and reasoning (<http://www.uky.edu/Registrar/bulletinCurrent/ukc.pdf>).

Students take one of the courses offered that “engage students in the fundamental process of science through the exploration of an area in science”

(<http://www.uky.edu/Registrar/bulletinCurrent/ukc.pdf>). Some of the courses that meet the requirement are “The Solar System,” “Human Ecology,” “Global Climate Change,” “Insect Biology,” “Endangered Planet: An Introduction to Environmental Geology” and



courses in Biology, General Physics and Chemistry. Both Physics and Chemistry have a 2-course series that must be completed to qualify as general education. A second general education category, “Quantitative Foundations” also includes some science courses, such as “Dynamic Earth” and “Quantifying the Bluegrass Water supply.” Goals of this element involve applying math and statistical techniques to solving real world problems.

For purposes of assessment, instructors for these courses choose a graded assignment from their class that demonstrates whether students have mastered the intended learning objective and upload it to Blackboard. From these, a sample is selected, stripped of identifying data, and given to faculty evaluators who use a rubric to assess the level at which students are meeting goals. Each evaluator assesses approximately 60 assignments at an estimated time of 15 minutes per assignment. As of this writing, the results from the first year of the new program are not available.

**Carleton College.** Carleton is a liberal arts school in Minnesota. Carleton is interesting for its philosophy of science program and of particular interest personally because of their current NSF sponsored program “On the Cutting Edge”, a series of workshops, both virtual and face-to-face involving geoscience teaching (<http://serc.carleton.edu/NAGTWorkshops/index.html>).

The liberal arts requirement at Carleton includes six “curricular exploration areas.” (<http://apps.carleton.edu/campus/registrar/catalog/current/programs/>) which must include 6 hours of credit in science course with labs.

As stated in the Carleton catalogue:

Modern citizenship requires an understanding of the processes and methods of the natural sciences. At least six credits are required in

courses that focus on developing an appreciation of the scientific study of the natural world. Courses *must include* a lab component to qualify (<http://apps.carleton.edu/campus/registrar/catalog/current/programs/>).

Between the 2010 and 2011 school years, the requirements at Carleton have changed from an 18-credit mathematics and natural science requirement to six credits of lab science and three courses designated “quantitative reasoning encounter.”

Departmental listings include a letter designating the requirements each course can fill. A few of the physics courses that meet the lab science and quantitative reasoning requirements are “Newtonian Mechanics,” “Gravity and the Earth,” “Relativity and Particles,” “Observational Astronomy” and “Environmental Physics.” Biology courses that qualify for either lab science or quantitative reasoning are “Genes, Evolution and Development,” and “Energy Flow in Biological Systems.” “Global Change Biology” meets the quantitative requirement but not the lab science requirement. Chemistry offers “Principles of Environmental Chemistry” in addition to several introductory courses that satisfy either of the requirements. Laboratory courses in geology include “Introduction to Paleoclimate Studies,” “Introduction to Environmental Geology,” “Mineralogy” and “Petrology.” “Geomorphology” also would qualify as a quantitative reasoning course.

**Michigan State University.** Designated a “peer institution” of Mason’s, on the George Mason University institutional research page, MSU has an Integrative Studies requirement with three core areas: Arts and Humanities, Biological and Physical Sciences, and Social, Behavioral, and Economic Sciences (<http://www.reg.msu.edu/AcademicPrograms/Text.asp?Section=110#s286>). A required eight credit hours in science includes two three-hour lectures and a two-hour lab

associated with one of the lectures. One of the courses must be in the biological sciences and one in the physical sciences. There are some alternative courses that can be substituted depending on major, and transfer students are required to show evidence of a similar set of natural science courses.

In contrast to most of the institutions examined here, MSU located general education science in the Center for Integrative Studies in General Science rather than in departments. Currently biology offerings are “History of Life,” “Insects, Globalization and Sustainability,” and “Applications of Biomedical Sciences.” The last two have associated 2-credit labs that require the lecture as pre- or co requisite. For physical science the allowed courses are: “Understanding Earth: Natural Hazards and the Environment,” “Visions of the Universe,” “World of Chemistry,” “The Mystery of the Physical World,” “Navigating the World,” “The Science of Sounds,” “Water and the Environment,” “Quarks, Space, Time, and the Big Bang,” and “Earth, Environment and Energy.” Most of these courses also have labs, but as with Biology, the labs have the lecture as either prerequisite or co requisite. Lab is not required to get credit for the lectures, as students only need one 2-credit lab.

The school instituted an assessment program for its general science requirement in spring of 2011. Thirty instructors volunteered to administer an assessment in their classes. Three assessments were given, each one to ten classes. An on-line survey designed by a committee in the Integrative Studies program was administered in ten classes, and Scientific Reasoning and Quantitative Reasoning surveys were given to the remaining classes. The Integrative Studies survey tested attitudes toward learning

science, understanding of science, and conceptual understanding of climate change.

(<http://cisgs.msu.edu/assessment.html>).

Among the goals of the integrative science program are: develop critical thinking and interpretive skills, increase knowledge about the scientific method and its usefulness in understanding the natural world, enhance appreciation of the role of knowledge, values, and ethics in understanding human behavior and solving social problems, and recognize responsibilities and opportunities associated with democratic citizenship and living in an interdependent world.

**University of Colorado Boulder.** A thirteen credit hour requirement for natural science general education makes the University of Colorado stand out among the schools I have examined. Students take a two-course sequence and a lab, but are required to take no more than two courses in any department (<http://admissions.colorado.edu/undergraduate/apply/transfer/courseequivalency>). The reason for this requirement may be to give students both depth in one particular science and breadth in exposure to at least two different science disciplines. Science majors are exempt from the general education requirement. Most of the standard sequences are also introductory courses for majors.

The university has 10 core areas, including a 3 to 6 hour quantitative reasoning and mathematical skills area. Interestingly, introductory physics courses are included as possible selections to satisfy this quantitative reasoning requirement. The writing requirement also has a number of courses that are specific to science, particularly in the required three credit upper division courses. Students interested in science could choose

“Developing Scientific Writing Skills” or “Writing in Physics: Problem Solving and Rhetoric.”

Courses offered in a sequence, with labs, range from the standard sounding introductory Astronomy, Biology, Chemistry, Geology and Meteorology to some tailored to the geographic area, “Introduction to Geology” and “Geology of Colorado” make one sequence, for example. In addition, there are a wide range of three credit courses, “Black Holes,” “Desert Meteorology and Climate,” “Creative Technology,” “Energy and the Environment,” “Sound and Music,” “Nutrition for Health,” “Plagues, People and Microorganisms,” and “Evolution and Creationism,” to name a few. The stated goal of the natural science requirement according to the website is to:

.....understand the current state of knowledge in at least one scientific discipline, with specific reference to important past discoveries and the directions of current development; to gain experience in scientific observation and measurement, in organizing and quantifying results, in drawing conclusions from data, and in understanding the uncertainties and limitations of the results; and to acquire sufficient general scientific vocabulary and methodology to find additional information about scientific issues, to evaluate it critically, and to make informed decisions ([http://www.colorado.edu/ArtsSciences/students/undergraduate/as\\_core.natsci.html](http://www.colorado.edu/ArtsSciences/students/undergraduate/as_core.natsci.html)).

In addition, the courses in natural science at the University of Colorado are intended to help students gain hands-on experience with science, hone their observational skills, and be able to evaluate science issues. Courses are intended to help students understand the dynamic nature of science and get a feel for history of science and current directions of development.

**James Madison University.** JMU is a public Master's awarding university of about 18000 undergraduates in Virginia. Its mission statement reads, "We are a community committed to preparing students to be educated and enlightened citizens who lead productive and meaningful lives"

(<http://www.jmu.edu/jmuweb/aboutJMU/administration.shtml>).

An emphasis on undergraduate hands-on learning is one selling point for the school and the website claims that 80% of undergraduates do research, practicums, internships, or student teaching. The general education program is called The Human Community. The purpose statement for general education says:

The Human Community is the core academic program of James Madison University. It is required of all students regardless of their major or professional program. The Human Community seeks to educate students in ways that have been fundamental to higher education and to thinking people for centuries. The philosophy of the program promotes the cultivation of habits of the mind and heart that are essential to informed citizens in a democracy and world community. The program is committed to helping students develop their ability to reason and make ethical choices; to appreciate beauty and understand the natural and social worlds they live in; to recognize the importance of the past and work towards a better future (<http://www.jmu.edu/gened/>).

The current program at James Madison is structured as a core curriculum organized into five clusters, Skills for the 21<sup>st</sup> century, Arts and Humanities, The Natural World, Social and Cultural Processes, and Individuals in the Human Community. The Natural World cluster has two tracks, with the second track designed for the University's Interdisciplinary Liberal Studies (IdLS) majors. The first track has a three-course requirement that must include one course from each of three groups. Group 1 consists of

math courses, ranging from “The Nature of Mathematics” through “Calculus 1.” Group two offerings are primarily in chemistry and physics and include courses such as “General Chemistry,” “Environmental Issues in Science and Technology,” “The Physical Nature of Light and Sound,” and “Energy and the Environment.” Group three includes courses in biology, geology, and astronomy, such as “Organisms,” “Human Physiology,” “Biological Anthropology,” “Physical Geology,” “Evolutionary Systems,” and “Astronomy.” At least one of the science courses must have a lab.

Track II is designed for IdLS majors who are preparing to be pre-K-8 teachers. These courses have a math requirement. Course offerings for this track include, “Fundamentals of Mathematics,” “Science Processes,” “The Science of the Planets,” “The Matter of Matter,” “Physical Science: Learning through Teaching,” and “The Way Life Works.”

Specific learning goals for Natural science at JMU are:

- Describe the methods of inquiry that lead to mathematical truth and scientific knowledge and be able to distinguish science from pseudoscience.
- Use theories and models as unifying principles that help us understand natural phenomena and make predictions.
- Recognize the interdependence of applied research, basic research, and technology, and how they affect society.
- Illustrate the interdependence between developments in science and social and ethical issues.
- Use graphical, symbolic, and numerical methods to analyze, organize, and interpret natural phenomena.
- Discriminate between association and causation, and identify the types of evidence used to establish causation.
- Formulate hypotheses, identify relevant variables, and design experiments to test hypotheses.
- Evaluate the credibility, use, and misuse of scientific and mathematical information in scientific developments and public-

policy issues

(<http://www.mscd.edu/aa/generalstudies/assets/pdf/resources/task/jamesmadisoncore.pdf>).

**Columbia University.** I chose Columbia University for this study because it has had a history of attention to liberal arts and general education and because it has a new approach to core science learning that includes university wide requirements. Most universities have a variation on the “menu” driven approach to general education, particularly in science. Columbia has attempted to build common ground in science with a focus on current research and topics of broad interest. In addition to a core requirement, students choose remaining science requirements from a selection of disciplinary courses.

The statement of purpose for Columbia’s core curriculum, and the specific science focus reads as follows:

The objective of the science component of Columbia College’s Core Curriculum is identical to that of its humanities and social science counterparts, namely to help students “to understand the civilization of their own day and to participate effectively in it.” The science component is intended specifically to provide students with the opportunity to learn what kinds of questions are asked about nature, how hypotheses are tested against experimental or observational evidence, how results of tests are evaluated, and what knowledge has been accumulated about the workings of the natural world. (<http://www.college.columbia.edu/core/classes/science.php>).

Students take “Frontiers of Science” in Fall or Spring of their freshman year. The course includes 12 mini-lectures delivered by four of the school’s research scientists. In addition to the lectures, students participate in seminar sections where they discuss the lectures, plan and carry out experiments and discuss implications of the science they are learning for society. To complete the natural science requirement, students take two



additional courses from a list of courses designed for non-majors, though they can also take introductory major's courses with instructor approval. A web book supplements the mini-lectures. The book is available to anyone on the web and might make a good resource for instructors looking for ways to raise the cognitive level of introductory science courses (<http://ccnmtl.columbia.edu/projects/mmt/frontiers/>).

**Arizona State University - Tempe.** Another of Mason's peer institutions, ASU- Tempe is a state university enrolling nearly 60,000 students in Fall 2011 ([http://uoia.asu.edu/sites/default/files/quickfacts/Quick\\_Facts\\_Fall\\_2011.pdf](http://uoia.asu.edu/sites/default/files/quickfacts/Quick_Facts_Fall_2011.pdf))

The general studies program at ASU-Tempe has five core areas: Literacy and Critical Inquiry, Mathematical Studies, Humanities, Fine Arts, and Design, Social and Behavioral Sciences, and Natural Science. Students must also complete courses in three awareness areas, Cultural Diversity in the United States, Global Awareness, and Historical Awareness. Courses that meet the natural science requirement are labeled SQ or SG.

SQ courses are designated quantitative natural science and students are required to take at least one course in this area. The SQ courses appear to be the basic courses in fields such as chemistry, astronomy, geology, and biology. SG courses are lab courses and include offerings such as "Bones, Stones/Human Evolution," "Dangerous World" from the Geology department, "Introduction to Climatology," and "Microbiology."

The stated purpose of general education at this school is "to prepare students for constructive and satisfying personal, social and civic lives" ([https://catalog.asu.edu/ug\\_gsr](https://catalog.asu.edu/ug_gsr)) as well as for a career and to impart general skills and

breadth to their education. The Natural sciences courses help students “appreciate the scope and limitations of science and its contribution to society.”

([https://catalog.asu.edu/ug\\_gsr](https://catalog.asu.edu/ug_gsr)). Laboratory credits are required because the laboratory is considered a key part in understanding science.

**Cloud Community College.** This small community college in Concordia, Kansas with two campus locations serving 11 counties in north central Kansas, was selected because the website contains detailed information about the general studies assessment program.

Three to five hours of lab science are required for most of the degree and certificate programs at Cloud Community College, although for Associate of Science degrees the requirement is 4 hours of biological science and 4-5 hours of physical science. Courses are departmental and relatively few in number with specific courses designated for majors in the Associate of Science program.

The learning outcome goal for natural science at Cloud is simple and straightforward; students should be able to demonstrate the ability to apply the scientific process. Instructors design an essay, project, or experiment that will show whether students have acquired this ability. A list of 11 abilities are targeted and assessed by rubric. The abilities include:

- Recognize the problem to be solved
- Follow written directions accurately
- Demonstrate use of applicable scientific techniques
- Apply deductive reasoning to develop an approach to the problem
- Follow safety guidelines
- Acquire data
- Display data in a clear and organized format

- Collect observations
  - Use observations and/or data to reach a relevant conclusion
  - Evaluate the validity of the conclusion
  - Express ideas, approaches, data and conclusions in a well-communicated format
- (<http://www.cloud.edu/faculty/assessment/reports/2008%20General%20Education%20Assessment%20for%20Science.pdf>)

The 2010 assessment report states that safety issues were not included in most reports in the set of artifacts presented for that year. In addition, error discussions were lacking. The report makes the point that instructors need to emphasize the missing parts and teach students how to report their methodology, another weak area. A 2008 dean's report suggested that more time should be spent in science departments discussing and improving understanding of assessment and applying assessment results to classroom changes (<http://www.cloud.edu/faculty/assessment/reports/2008%20General%20Education%20Assessment%20for%20Science.pdf>).

One interesting thing here is that the assessment has changed somewhat over time and has influenced what happens in the classroom, an example of where teaching to the test may be valid. Safety considerations have apparently been an issue since the first round of assessment, which seems to show that this is either something difficult to demonstrate in a student assignment, or is, perhaps, an area some instructors neglect. The paucity of error reporting is more easily addressed if error analysis is considered a valuable part of doing science at the general education level.

The assessment cycle shows science assessments every year

<http://www.cloud.edu/faculty/assessment/Assessmentpdfs/General%20Education%20>

[Assessment%20Cycle.pdf](#)). Cloud Community College pays an outside consultant to assist the assessment effort and has a committee with department representatives. The school includes students on assessment committees. The committees rely on evaluations, surveys, exit interviews and, primarily, course artifacts to evaluate mastery of the subject. The assessment cycle uses results of the assessment to suggest changes in courses. After divisions, departments and faculty have evaluated the results of the assessment, general education goals, and pedagogy are modified to incorporate the recommended changes into syllabi.

**Virginia Tech.** Virginia Tech has named its program for general education “Curriculum for Liberal Education” (CLE) (<http://www.cle.prov.vt.edu/>). The program has a 6 – 8 credit hour requirement for natural science, with some majors requiring a sequence including labs. The courses are drawn from departmental offerings. According to the school’s website the CLE is:

Designed to empower students with a broad base of knowledge and transferable skills through exposure to multiple disciplines and ways of knowing, the CLE seeks to create the conditions for growing creative and intellectual engagement; civic, personal, and social responsibility, and lifelong learning. The CLE is designed to foster and develop:

- intellectual curiosity and critical thinking
- the capacity for collaboration and creative problem solving
- the ability to synthesize and transfer knowledge
- intercultural knowledge and understanding
- strong analytic, communication, quantitative, and information literacy skills
- ethical reasoning and action (<http://www.cle.prov.vt.edu/>).

A message to students about the program stresses the need for a broad base of knowledge and transferable skills. The program is intended to foster curiosity and critical

thinking, as well as a variety of skills. Students are expected to get what they need to thrive in a global environment that is changing and challenging. The university intends the CLE to be the foundation for a lifetime of learning (<http://www.cle.prov.vt.edu/>).

According to minutes of the CLE curriculum committee, the current distribution program is being revised with the goal in mind of preparing for the future and the changes that will come. The committee seems to desire to keep the process somewhat flexible with multiple paths toward satisfying requirements. They will begin by clarifying goals of the CLE program

([http://www.cle.prov.vt.edu/ucce/minutes/UCCLE%20Minutes%209\\_7\\_11.pdf](http://www.cle.prov.vt.edu/ucce/minutes/UCCLE%20Minutes%209_7_11.pdf)).

Current goals for natural science are:

1. Describe the methods of inquiry that lead to scientific knowledge and be able to distinguish science from pseudoscience;
  2. Evaluate the credibility of, use, and misuse of scientific information;
  3. Recognize how science is self-correcting through formulation of hypotheses, testing of these hypotheses by carefully designed experiment or by observation, and by appropriate modification of hypotheses;
  4. Given a theory or model, make predictions about the results of an experiment or observational study, observe the outcomes, and compare the predictions with the outcomes. Recognize how to reason scientifically, how to make appropriate assumptions, and how to use scientific methods and tools to solve basic problems within natural science;
  5. Organize scientific information and data into trends and patterns using spatial, graphical, symbolic, and numerical methods to sort, analyze, and interpret natural phenomena;
  6. Communicate effectively the results of a set of scientific experiments or observations;
  7. Provide examples of the interdependence between social or ethical issues and developments in science and technology;
  8. Give examples of the roles of diverse individuals and approaches in advancing scientific knowledge
- ([www.cle.prov.vt.edu/guides/area4.html#3](http://www.cle.prov.vt.edu/guides/area4.html#3))

Courses that meet the requirements appear to be basic introductory courses in biology, chemistry, environmental science, forestry, geosciences, and physics; most, though not all, with associated labs separately numbered labs.

**Old Dominion University.** The general education program at ODU is divided into two parts, “Skills” and “Ways of Knowing.” The purpose of the program is to give students a broad knowledge base as well as help them find areas of interest. The 8-hour science requirement comes under “Ways of Knowing.” Although many of the allowed science courses are in a sequence, a sequence is not generally required, unless the major specifies it. Several of the courses are designated for non-science majors. “Conceptual Physics,” “Introductory Oceanography” and “Introductory Astronomy” as well as “Earth Science” and “Biology for non-majors” are examples.

(<http://www.odu.edu/ao/familyconnection/docs/PREVIEW%20General%20Education%20Requirements%202010-2011.pdf>).

ODU has a plan for a 4-year assessment program for general education competencies. In the 2011-2012 school year, scientific reasoning was in the reporting and improving stage. Other parts of the process are Planning, Assessing, and Implementing. Faculty members have developed a scientific reasoning test that is administered at the end of the general education science courses. Goals for students at the end of these courses are that students will:

- Demonstrate comprehension of a body of scientific knowledge
- Develop ability to apply concepts to new situations, solve problems, and interpret evidence that is presented in various formats, such as verbally, numerically, and graphically as appropriate to the content of the course.

- Be able to describe the domain and methods of scientific thinking, and be able to distinguish between questions that can and cannot be answered scientifically.
- Describe the role of experiment and observation in the development of scientific theory and knowledge.  
(<http://www.schev.edu/AdminFaculty/VAG/4%20year/AssessODU.pdf>)

The ability to apply concepts to new situations, solve problems and interpret evidence that is presented in various formats, and being able to describe the domain and methods of scientific thinking and distinguishing between questions that can and cannot be answered scientifically, are marked as competencies included in the ODU Quality Enhancement Plan (QEP) topic, “Focused Thought: Reasoning through Writing and Research.” A footnote in the table of assessments indicates that assessments for these competencies may be modified as the QEP is developed

(<http://www.schev.edu/AdminFaculty/VAG/4%20year/AssessODU.pdf>).

**Virginia Commonwealth University.** Located on two campuses in Richmond, Virginia, Virginia Commonwealth University (VCU) is a research university with 32,000 students, (<http://www.vcu.edu/about/>) with a primary focus on health sciences.

Approximately 21,000 undergraduates were enrolled in 2010

(<http://www.vcu.edu/cie/analysis/facts/factbook.html>) most of them traditionally aged full-time students.

Goals of the general education program as reported on the university website are as follows:

The purpose of general education courses in the College of Humanities and Sciences is to provide a foundation for lifelong learning for its students. This foundation includes the acquisition of information, the capacity and the propensity to engage in inquiry and critical thinking,

the use of various forms of communication, an awareness of the diversity of human experience, an understanding of the natural world, and an appreciation of the responsibilities of people to themselves, to others and to the community.

([http://www.has.vcu.edu/students/ug\\_edu/gen\\_edu/requirements.html](http://www.has.vcu.edu/students/ug_edu/gen_edu/requirements.html))

Natural science is included in the Science and Technology requirement. Students take 7 – 9 credit hours that include a physical and a biological science with at least one lab. The Technology component can be fulfilled with a three credit class, or passing the Computer Literacy Exam. Some of the courses included as natural science offerings for the Bachelor's degree include "Biological Concepts," "Science of Heredity," "Environmental Science," "Chemistry and Society," "Chemistry in The News," "Foundations of Physics," "Elementary Astronomy," and "Wonders of Technology" as well as other introductory courses in Biology, Chemistry, and Physics that meet the general education requirement for science majors. The list of courses in the June 2011 bulletin are slightly different from those listed on the general education webpage and include, in addition to those listed above, "Crime and Science," and "Energy."

(<http://www.pubapps.vcu.edu/bulletins/about/?uid=10030&iid=30971>)

Specific science and technology goals as reported by the university are designed to "enhance students' literacy in science and technology, including an understanding of the natural world, experience with the fundamental ideas and methods of the sciences and greater scientific literacy, particularly in relation to energy, evolution, and evaluation."

(<http://www.pubapps.vcu.edu/bulletins/about/?uid=10030&iid=30971>)

**Northern Virginia Community College.** General science offerings and goals of this large community college located at seven campuses in northern Virginia are



especially important for this study since Mason receives a large number of transfer students from this institution.

NVCC adheres to the goals for general education established by the Virginia Community College system. The catalogue statement of the scientific reasoning goal defines qualities indicating competency as follows:

A person who is competent in scientific reasoning adheres to a self-correcting system of inquiry (the scientific method) and relies on empirical evidence to describe, understand, predict and control natural phenomena. Degree graduates will demonstrate the ability to:

1. generate an empirically evidenced and logical argument;
2. distinguish a scientific argument from a non-scientific argument;
3. reason by deduction, induction and analogy;
4. distinguish between causal and correlation relationships;
5. Recognize methods of inquiry that lead to scientific knowledge.

(<http://www.nvcc.edu/about-nova/directories--offices/administrative-offices/assessment/outcomes/vccsgoals/index.html>)

NVCC has been using the Quantitative Reasoning/Scientific Reasoning Test (QR/SR) developed by James Madison University to assess both quantitative and scientific reasoning, with the most recent reported results on the NVCC website from 2008-2009. The report is somewhat confusing since objectives are labeled with letters in the VCCS goal statements and by number in the table of results for the scientific reasoning part of the assessment. However, if it can be assumed that “a.” matches Objective 1 and so forth, the 1092 students tested scored 50% for generating an empirically based and logical argument, 72.5% for distinguishing a non-scientific from a scientific argument, 50.7% for reasoning by deduction, induction and analogy, 53.5% for

distinguishing between causal and correlation relationships, and 60.7% for recognizing methods of inquiry that lead to scientific knowledge. These numbers by themselves mean little without a standard for comparison, but may serve as base-line data for future years.

Since Mason is moving toward new assessment methods for scientific reasoning, it is unlikely that it will be easy in the near future to compare scientific reasoning competency of students who matriculate from NVCC to that of students who take their science classes at Mason.

The following table is a summary of institutional goals for natural science for the institutions in question. Goals have been distilled and summarized from the institutions' web pages.

Table 3: Institutional goal statements

Institution	Science Goal 1	Science goal 2	Science Goal 3	Science goal 4 <sup>8</sup>
George Mason University (through Fall 2011)	Provide students with an understanding of natural science.	Emphasize the critical approach of the scientific method, the relation of theory and experiment.	Students should be able to understand and use quantitative and qualitative information	Understand the development and elaboration of major ideas in science
George Mason University (new goals approved fall 2011)	engage students in scientific exploration;	foster curiosity	enhance student enthusiasm for science	Enable students to apply scientific knowledge and reasoning to personal, professional and public decision-making
Macalester college	Develop basic familiarity with counting, measurement, estimation and data analysis	Increase capacity to ask and answer questions in a manner appropriate to using quantitative tools	Develop ability to understand when use of quantitative tools is or is not appropriate	Learn approaches to collecting, interpreting and presenting information based on numerical, logical and statistical skills
University of Hawaii Manoa	Know the aims and methods of science	Reason and analyze effectively	Appreciate complexities and potentialities of the human experience	Exposure of different domains of academic knowledge
University of Kentucky	Be able to identify multiple dimensions of a good question	Find and judge quality of information	Explore ethical implications of differing approaches	Develop potential solutions based on sound evidence and reasoning
Carleton College	Acquaintance with modes of inquiry in science	Understanding of processes and methods of the natural sciences	Appreciation of the scientific study of the natural world.	evaluate construct and communicate arguments using quantitative reasoning

<sup>8</sup> Goals have been condensed and summarized in most cases. References are included where relevant in preceding text.

Michigan State University	Be able to describe major concepts in science and understand contexts in which they were developed	Be able to discriminate between ideas that do and do not constitute proper subjects for science.	Give examples of how scientific understanding evolves and use scientific approaches to problem solving in the natural world	Learn to value the efforts of scientists as they address practical needs and research matters of fundamental and lasting importance.
University of Colorado	Enhance literacy and understanding of one science discipline	Gain hands-on experience with scientific research and observation	Be able to critically evaluate science information and conclusions	Understand uncertainties and limitations of results
James Madison University	Describe the methods of inquiry that lead to scientific knowledge and be able to distinguish science from pseudoscience	Use theories and models as unifying principles that help us understand natural phenomena and make predictions	Illustrate the interdependence between developments in science and social and ethical issues	Use graphical, symbolic and numerical methods to analyze, organize and interpret natural phenomena
	Discriminate between association and causation and identify the types of evidence used to establish causation	Formulate hypothesis, identify relevant variables and design experiments to test hypotheses	Evaluate the credibility, use and misuse of scientific and mathematical information in scientific development and public-policy issues	Recognize the interdependence of applied research, basic research and technology, and how they affect society.
Columbia University	Introduce students to exciting ideas at the forefront of scientific research	Inculcate habits of mind common to a scientific approach to the world		
Arizona State (Tempe)	Help students appreciate the scope and limitations of science and its contributions to society	Knowledge of methods of the scientific inquiry and mastery of basic scientific principles and concepts.	First-hand exposure to scientific phenomena in the laboratory	Developing and understanding the concepts, principles, and vocabulary of science
Cloud Community College	Demonstrate the ability to apply the scientific process	Recognize problem, follow instructions, demonstrate techniques, apply deductive reasoning	Follow safety guidelines, acquire and display data, collect observations and use them to reach relevant conclusion	Evaluate validity of conclusion and communicate process and results.

Virginia Tech	Describe methods of inquiry and distinguish science from pseudoscience	Evaluate scientific information and communicate results	Recognize self-correcting nature of science, its interdependence with social issues and roles of diverse individuals and approaches	Be able to start from theory and work through to using scientific methods and tools to solve basic problems, as well as organize information and data into trends and patterns
Old Dominion University	Demonstrate comprehension of a body of scientific knowledge	Develop ability to apply concepts to new situations, solve problems and interpret evidence	Be able to describe domain and methods of scientific thinking and distinguish between question that can and cannot be answered scientifically	Describe role of experiment and observation in the development of scientific theory and knowledge.
Virginia Commonwealth	Enhance students' literacy in science and technology.	Develop understanding of the natural world.	Gain experience with the fundamental ideas and methods of the sciences	Achieve greater scientific literacy, particularly in relation to energy, evolution, and evaluation.
Northern Virginia Community College	generate an empirically evidenced and logical argument	distinguish a scientific argument from a non-scientific argument	reason by deduction, induction and analogy	distinguish between causal and correlation relationships and recognize methods of inquiry that lead to scientific knowledge

## **Faculty Interviews**

I conducted interviews with seven professors at Mason. The contacts were made by listing all faculty members who taught general education classes in any science discipline during the period Summer 2009 through Spring 2011. Following the process outlined in the Methods section, I began sending emails requesting interviews to faculty who met the criteria, with a follow up request approximately two weeks later.

It seems likely that those who responded either recognized my name from the department, were genuinely interested in issues involving general education science, or are kindly disposed to graduate students. One of the faculty members who agreed to an interview is personally committed to giving back to the university by teaching general education, two have been involved in considering new general education goals and all expressed interest in helping students learn enough science to function well in society. Based on the interviews it seems safe to assume that these faculty members want to do the best possible job of teaching the courses. That leads me to postulate that any gaps uncovered in terms of understanding and conveying general education goals in the courses taught by the interviewees might extend to other general education science courses, particularly those taught by those less connected to the university.

The list of interview questions for instructors is in Figure 2. Instructors were given the questions, as well as the Mason goals statements, via email before the interview. They were also given a paper copy of the goals at the appropriate time. Questions were not always asked in the order given and at times I backtracked to pick up questions the conversation had skipped over.

Figure 2: Instructor interview questions

<p><b>General information questions:</b></p> <ul style="list-style-type: none"><li>• How is the course structured – lecture/lab combined, coordinated particular lecture with particular lab sections, any lab for any lecture, stand alone lecture and lab, distance education component? How many instructors are involved in teaching this course including TAs and lab instructors?</li><li>• Do you know when the course was developed and who originated it? What modifications have you made?</li><li>• How were the syllabus and course outline developed? Did you inherit the course from someone else, and if so have you made changes you consider significant to the syllabus and course design?</li><li>• Do you coordinate with other instructors teaching other sections of the course or with associated lab sections?</li></ul> <p><b>Goals questions:</b></p> <ul style="list-style-type: none"><li>• What are the top three or four things you hope students take away from your course?</li><li>• How do you structure what and how you teach to support those goals?</li><li>• What do you think are the main things you students learn that will stay with them as they graduate and move into jobs?</li><li>• How are the goals included in the documents you shared with me, the syllabus and course outline or other material? Can you point to lessons and activities that support the goals you have for student learning?</li></ul> <p><b>Alignment questions:</b></p> <ul style="list-style-type: none"><li>• Are you familiar with the general education goals statement for the university?</li><li>• How did you find out about the goals of general education and general education natural science at GMU?</li><li>• I am going to give you a copy of the university goals statement. Take a few minutes to read it over before we move on.</li><li>• If you were to examine general education courses in your subject area at GMU, do you think they would meet these general education goals?</li><li>• How do you think your course and the way you instruct it support university general education goals for science?</li></ul> <p><b>Instructor goal input questions:</b></p> <ul style="list-style-type: none"><li>• If you were to redesign the university statements of goals for general education science, what would you include?</li><li>• What would you leave out?</li><li>• What do you think is the most important outcome for students taking a general education science course?</li></ul>
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Table 4 lists code names of the participants, their primary departmental affiliation at the time of the interview, and courses taught relevant to general education natural science. Faculty members included a range of faculty ranks including full professor, term and adjunct. Interview narrative follow the table. Brief summaries of the responses addressed by the research questions come in the section in this chapter titled “Findings.”

Table 4: Faculty information

Code Name	Courses taught
Auriga	University 301, Honors 110, Astronomy 101-102 (course numbers have changed)
Vela	Physics 106, 262, 266
Aquila	Astronomy 111, 112, 114
Cetus	Geology 101 and 102
Orion	Astronomy 111
Libra	Chemistry 211, 212
Cygnus	Biology 103,104, 213

**Auriga.** Auriga is a physical science professor who has taught a variety of science courses, including astronomy and physics, and courses in Honors and University 301. Much of the interview centered around the University 301 course, “Great Ideas in Science,” which is a non-lab survey course covering foundational ideas in all the major science branches.

Auriga recalled hearing about current University goals and has strong ideas about the nature of appropriate goals. A primary one is that students be able to read the newspaper on the day they graduate. In this view, the role of college general education science is to help students create something like a filing cabinet with science CDs that they can mentally access when they read or discuss current issues in science. Because there are a limited number of foundational ideas, students can start with a science question that is current and work back to one of these principles to understand the science they read about in the popular press. Though the current University 301 course does not have a lab, this instructor also taught in PAGE, Mason’s alternative general education program developed in the early 1980s, and developed labs significantly different from



traditional disciplinary labs. Instead of a “cookbook” experience, where, in this instructor’s experience, students often worked backward from answers to data, labs in PAGE were open-ended investigations. Examples included doing a home energy loss audit, and charting the changing elevation of the Sun at noon over a semester. The laboratory in this case was the outside world. When the PAGE program evolved into the Honors College this professor moved to teaching the University 301 course that did not have lab space or a lab requirement. This professor does not miss having a lab component and feels that labs contribute little to the primary goal of developing a framework for understanding the great ideas of science.

When asked about assessment, Auriga expresses doubt about what should be tested. Scientific literacy, in terms of understanding everything from stem cells to plate tectonics, is not found in just one course, unless it is a course like University 301. Thinking like a scientist is not something that this instructor believes most people do or will do, but scientific literacy, knowing about a relatively small number of foundational concepts, is a bottom line necessity. While students may have gotten some exposure to these ideas in high school, a role of college natural science is helping students fit together the pieces gotten in high school science but not merged into an integrated worldview.

When asked about the specific university goals for natural science, Auriga rejects the idea of being able to use and interpret data, stating that is something students at this level cannot do. Instead, Auriga returns to the idea that students should be able to read the newspaper on the day they graduate, have a broad enough background to function as citizens, and be able to participate in debates, all activities that don’t involve taking or

interpreting data. Auriga also points out that scientists think quantitatively which is not natural for humans. On the other hand, historical case studies illustrating the scientific process are part of the University 301 course and the instructor hopes to help students be able to answer questions such as “how do you know the universe is expanding?” with measurements as evidence. The process of science weaves through most lectures.

Auriga also mentions surveys of employers who want students who can think creatively about problems and can communicate well. One suggestion this instructor makes is that students need more writing practice and instruction in writing well. On the topic of general education classes in other subjects, this instructor would do an analogous practice in all areas, focusing on cultural literacy to make sure people have the knowledge they need as a starting point in a changing world.

**Cetus.** Cetus is a professor in the physical sciences who has taught the lecture portion of a general education lecture/lab combination geology class with large enrollments. Cetus based the course on what had been done in previous terms, though the emphasis was shifted a bit to match Cetus’ research specialty.

The course is structured around the textbook and is directed toward helping students learn the basics of geology - what the earth is made of, processes that are important in shaping the earth as it is today, and earth’s history. Course goals were structured around these topics though they are not explicitly outlined.

An important theme for Cetus is that it is important to structure the class by building on what students have learned earlier. Definitions, foundational processes, and understanding of rocks and minerals serve as building blocks for later understanding of

geological processes. The foundational materials are not discussed and then dismissed, but once introduced, recur throughout the course.

Cetus hopes that some topics will stay with the students long after the course: the basic structure of the earth, the difference between continental and ocean crust material, the reason for mountains, why earthquakes happen, and other topics that recur. Cetus relates topics in class to current events, such as the earthquakes in Chili and Haiti. An important part of the class is making connections between the real world and the lecture material. A goal in making these connections is to help students know why a geological event happened, and to help them remember what they learned.

Cetus mentioned some pedagogical techniques used in class to pique interest, such as starting class with a question. For example, an opening exercise might be to display a world map of volcanoes and ask students to estimate how many volcanoes there are in total, a number that is often surprising to students. As a pedagogical technique, Cetus does not distribute power point slides to help encourage students to come to class, which Cetus feels is important to doing well.

Cetus had seen the general education goals and thought that perhaps they had been distributed at orientation. The class perfectly fits the goals about developing understanding of natural science, but as the class is specifically about geology, Cetus does not teach about natural science in general, although the course weaves in physics and chemistry as well as geology. What science does best for students, this instructor maintains, is developing critical thinking skills, which means students need to be able to critically evaluate information, not just absorb it.

When asked about the scientific method, Cetus responded that the class is oriented toward information; there is a lot of information to convey. As Cetus put it “We don’t talk about why, about process, about how we know what we know. That said...lab is where that happens.” The labs are coordinated with lectures, so Cetus feels the students hear about a topic in lecture, then get a chance to discover it in a different way in lab. However, Cetus does use the first lecture to talk about “understanding science” using materials available on-line from UC-Berkeley, particularly a diagram of science flow, which includes the idea that science is a social activity and that science investigations have a number of possible starting points. Cetus makes the point in lectures that “science isn’t just received wisdom,” rather it is continually being refined and is open to challenge.

The labs themselves are opportunities to check experimentally what has been covered in lecture. The labs are structured to help students learn how to do certain things, then do it themselves. Methods are taught and then students figure out what is going on in terms of geology as they conduct experiments using the methods. In some cases, students use a set of data to get a chance to do science discovery. According to Cetus, labs, rather than lecture, are the place most likely to address quantitative reasoning, one of the Mason goals. Cetus points out that major ideas in the discipline are the prime focus of the lecture part of the course. Cetus gives as an example, plate tectonics, and how it works, a relatively new concept and topic in geology, and covered in depth in lecture.

The Mason philosophy of general education document “Life, Liberty, and the Pursuit of Happiness” document (see appendix A) is something Cetus finds “laudable, but very abstract.” What is missing for Cetus is how to put these ideas into practice.

For assessment, Cetus would like to see pre- and post- tests that were similar for all the sciences, but using specific content to match the course. Rather than a general test for natural science, this would enable us to see if an individual course is meeting the goals of general education natural science.

The most important outcome Cetus sees for general education students is that they be able to critically evaluate data of all kinds, within science and outside of science. A two-semester sequence of eight credits would be preferable to the current arrangement which, for some students requires only one lab and for most does not require a sequence.

**Aquila.** Aquila taught a summer lecture astronomy course that fulfills general education requirements. Aquila used the syllabus of another lecture instructor, with some modifications, to structure the course, and relied on the publisher produced power point presentations for lecture presentations.

Aquila’s goals for the class included encouraging lifelong interest in astronomy, helping students understand how science works, and helping students develop skills that will enable them to evaluate public policy when it comes to science, and will encourage them to support science efforts in the public sphere.

Some of the techniques Aquila used to help support these goals involved “hands-on” exercises to help students develop a sense of scale and an understanding of important processes. Aquila developed an exercise involving solar panels on the Mars rovers to

support the third goal of evaluating public policy. Students looked at the science and technology involved in a current government sponsored science program, a real world case, in order to see the importance of science in planning projects and evaluating results.

Aquila states that students may have a “so what” attitude to what they learn in general education science and are primarily concerned about their grades. Aquila used class discussion in the small (approximately 40) summer class to try to link learning and grades, saying, “If they can state the point to the satisfaction of their peers they have definitely learned....and so I try to factor in a class participation grade.” One class discussion is about the syllabus, which includes the goals for the course, though they are not necessarily explicitly discussed.

An important take-away in this instructor’s view is that students realize that science does not have all the answers. On the other hand, enthusiasm for the natural world can be passed to future generations and should be part of what students take away from the course.

Aquila was not familiar with Mason’s goal statements, which were not listed on the goals for the course in the inherited syllabus, and did not agree with them. Aquila feels an educated person should have learned something about the philosophy of science, the use of language and other topics in the course of a college education, which would include science.

After further discussion, Aquila wondered if perhaps the goal about understanding natural science is more of a thesis statement and the other goals specific manifestations of the thesis. As far as the other goals go, Aquila believes the scientific method is

misunderstood and simplified even by teachers. Some of the words in the simplified outline of the method are misunderstood. Examples include “theory” and “hypothesis” with people not understanding that in science saying something is a theory means it is well established. Students get the reverse idea. Relation of theory and experiment is designed to be part of the lab, but Aquila wonders if the historical emphasis (looking at theory and experiment using historical cases) is a waste of time. One example offered by Aquila of quantitative thinking in astronomy is using various wavelengths to observe objects in the sky. Depending on the wavelength, each different part of the spectrum reveals something different. Aquila would like to see more qualitative discussion, for example, letting students make the case for and against defining Pluto as a planet, as part of an effort to get students to think critically. Another example might be teaching about the theory of solar system formation and looking at the major ideas that support it, then looking at extra solar planets and seeing how “it immediately throws a monkey wrench into all your theories about how planets form. That’s good, you say, maybe science doesn’t have all the answers.”

The last goal, developing and elaborating on major ideas in science, is too often misinterpreted to mean students should be able to list and repeat specific science ideas, which Aquila does not see as getting at the major ideas they should learn. An addition to the goals that would be important would be helping students know where they fit in the environment. It would apply to all the basic sciences. In addition, students should perhaps have a chance to evaluate science policy. Should we spend money on a return to the Moon, send astronauts to Mars, or concentrate on missions to planet Earth? Using

such questions would be a route to get students to start thinking clearly about what the space program is for, and how best to use public funds.

While it might not be so much a goal as a procedure, Aquila would like to see instructors show respect to students who are capable of thinking, but may not always have a background that is as solid as students at some elite schools. Students themselves do not know anything about the learning goals set by Mason, Aquila believes, and even if learning goals were explicitly stated in the syllabus, most students would probably skip over them to look at the grading scheme.

**Vela.** Vela teaches a small enrollment physics class classified as general education, but usually taken by students majoring in technical fields. Most of the students are required to take this course as part of the major, and for them it satisfies the general education natural science requirement. The course Vela teaches is the last in a sequence. It is associated with a lab and has recitation sections that focuses on problem solving.

The lecture and lab are somewhat coordinated, although Vela notes that sometimes labs experiments are done before corresponding lectures. This class picks up where the one before left off and is structured around a textbook.

The goal Vela cites as most important is physics concepts “How we explain the world.” Vela stresses the importance of demonstrating concepts that relate to the course material. Particularly for those students who are not majoring in the subject, and may not fully understand the associated mathematics; it is important for students to understand how the physics explains the world. They need to understand, as Vela puts it, “...there’s a cause and effect. And you know, seeing how things come about. It’s not magic.” Vela



often uses toys and everyday objects to carry out demonstrations, "...simple things they might have seen in their daily lives. You know, table top kinds of demos."

A goal with the simple demonstrations is to help students relate daily events in their lives to physical processes.

Vela assigns readings and assumes students have done the reading. The check on the process is whether or not they can do associated problems. Vela acts as a "filter" in lecture, emphasizing what is important. Vela also stresses that while formulas are given on the test, it is critical that students understand them, know where they came from and be able to differentiate formulas that may look similar in order to know when they are useful and when not.

Vela had not seen the "Life Liberty and Pursuit of happiness" document and responded that while the word "life" did not seem to fit; the purpose of a liberal education is to learn how to learn. For this instructor, learning to learn would be a goal for all students in the class. Concerning freedom, Vela says, "I think - freedom to seek knowledge and wisdom. It's something we should instill in the institution..." On the other hand, this professor doesn't see strong evidence from looking at the general state of the country that college educated people deal well with concepts such as evolution or renewable energy and in fact "...they just don't think through carefully what science is telling them." A sense of apathy, just not caring, is a worry, although Vela thinks that those with more education do seem to think more about world problems than others do.

Vela finds the idea that general education promotes the pursuit of happiness is an interesting question because “...that’s what our goal is, that you have a diversity of topics that you appreciate life better.”

The specific natural science goals resonated with Vela who feels they capture the cornerstone of what a basic science course should be. Specific goals may be treated in different parts of the course creating a kind of resonance. For example, lecture material might lead to talking about historical links and scientific ideas. In some cases, experiment drives theory, then “when you go to a laboratory class you kind of learn the theory and then you actually do the experiments so that “...it completes the cycle.” A concern in this model for Vela is that teaching assistants do the labs and recitations, so that in the lab students may miss the deeper understanding of the origin of the equations they use. Vela agrees with the natural science goals of quantitative and qualitative elements in these classes and points out that it is intrinsic to physics to use quantitative reasoning. As far as the part of the course where these things happen, recitations are used for problem solving, but lectures involve derivation and problem solving as examples as well.

Vela identifies the two most important goals of general education science as critical thinking and scientific method, followed by the relationship between theory and experiment and how that relates to the scientific method. Vela feels there is some question about whether engineers graduate with a sense of what the scientific method is “...they are so mechanistic in terms of the way they think and train...”

Vela has a strong interest in creativity and making connections between art and science and talks about the need for good art to have some kind of logic, just as good science does. Critical thinking is expressed in the medium of art as a kind of analog to critical thinking, which is identified with the scientific method in science. Science and art can influence each other. Drawing connections between art and science, Vela points out that artists might use science as inspiration, but more important is the way scientific thought can influence thinking for artists. Perhaps, on the other side, artists can verbalize the “ah ha” moment, the result of trial and error processes, that might help scientists to incorporate this more fully into the search for scientific truth. A main theme for this professor seems to be the creativity that is part of the sciences as well as of the arts.

**Orion.** Orion teaches a large enrollment astronomy lecture course.. A driving force for Orion is the idea that students taking general education science are not likely to ever take another science course and it is important to prepare them to make educated decisions as citizens in a world that will present ever more thorny questions involving science and its applications as students move into their adult lives. This instructor also mentions choosing to teach this course as a kind of pay back to the university and the people of the state.

Orion has chosen to use a text for introductory astronomy with a relatively high level of math compared to those used by some of the other instructors in the discipline. The reason Orion gives for this is that it is important to give an opportunity to students who are prepared to work with more mathematical treatments of astronomy content in order to get a better understanding. While math is not the primary topic, and missing

questions in this area will not reduce grades more than about half a letter grade, real understanding in science requires a mathematical approach as well as a conceptual one. The Copernican hypothesis, that things are the same throughout the universe and the scientific method are also addressed and fit under quantitative and qualitative reasoning.

A fundamental goal for Orion appears to be helping produce a scientifically literate population. Basic physics is elaborated where necessary and the instructor makes an effort to go into as much depth as possible, keeping in mind that this may be the last science course these students will take. Orion's perception of why students enroll in this class is that there is a certain amount of interest and also that students perceive it as being an easier option than some other possible courses.

Some important topics the instructor would like the students to retain include a sense of the size and scale of the universe and stewardship of the Earth, something highlighted by differences between Earth's current atmosphere and the runaway greenhouse effect that makes Venus uninhabitable. Students need to make that connection and need to have enough of a grasp of basic physical processes to be able to make good choices in their adult lives as they need to deal with issues of climate change and biotechnology among others. Students will need to evaluate science information to make good choices.

The method of science in this astronomy class is touched on mainly in the historical background to the topic, although it also enters in in a discussion of global climate change. An important part of the story of how astronomy developed has to do with the development of science itself and conflicts that occurred between, for example,

Galileo and the Catholic church as the idea of objective science was taking shape.

Science process also comes in in a discussion of climate change, a topic that Orion feels is a vital current science issue and relevant to a course on solar system astronomy. The public, as well as students in this class, can, and should understand and deal with it in a serious way. Understanding climate change requires understanding multiple interactions on earth and is a more complex topic than is addressed in some introductory courses, but relevant to astronomy. Orion does speculate that students may retain most of what they learn only subliminally, but that it will affect their judgment on issues.

Orion uses humor and a relaxed teaching style to reduce the distance between instructor and students. Showing that scientists are human, and making the subject entertaining, reduces distance between the instructor and student and, perhaps, between students and science. Orion uses various techniques to illustrate concepts, included drawing word pictures and using objects such as the laser pointer and erasers to illustrate star motion or accelerations. Printable power point notes on line allow students to keep up with lecture and take notes without racing to keep up with slides and animations. They can just annotate the printed notes. Judging from the instructor ratings available on the Mason website, this professor seems to be well liked by students who give the class high ratings in nearly every scored element.

Orion's underlying philosophy about science is that it is a human endeavor done by people who are fallible, but often passionate about science and the world. A goals of teaching is to show that objective science does move in the direction of uncovering objective truth, though human egos and foibles superimposes ripples and eddies on the

progression. Students come in with preconceptions and social mores, and it is important to use available tools to get through to them scientifically, humanistically and emotionally at times. This lecturer tries to make class something worth going to for the students.

Orion says the labs associated with lecture are like a black box, they are disconnected and the attempts that have been made to coordinate seem to have fallen by the wayside, but advises students to take both lecture and lab at once to get the synergy of doing them together..

When asked about what might be desirable changes to the Mason goal statements this faculty member suggested including some type of ethics statement. Society in general makes ethical decisions regarding science and what to fund. Our students should be prepared and able to make those choices. Some way of linking science and societies values should be part of the content. Orion addresses this through the climate change issue and uses on-line articles to illustrate what the evidence shows and how controversy has led to a strong consensus about what is happening. A goal would be helping students learn to think for themselves and to help them understand that science is not inaccessible, that there are choices to be made and they are capable of understanding and evaluating science at that level.

This instructor feels a responsibility to be in the general education classroom and to make the course as rigorous as possible, but also to stimulate interest in students, partly by being interested as an instructor.

**Libra.** Libra teaches a large enrollment general education Chemistry course. The course is coordinated with a required lab and is a foundational course in the discipline. One of the things this professor noticed, because of student complaints, was that there was no time to do significant problem solving in the lecture period, and students struggled with learning how to do it. The professor encouraged students to request a discussion or recitation section which led to the establishment of a tutoring center for chemistry and then to a computerized testing center for quizzes and exams. Students began to use the center, staffed by graduate students, after the introduction of graded quizzes. Students in general seem to be doing better now on the exams and test scores have improved according to Libra. While the testing center and on-line quizzes were an innovation, the subject matter for this class is relatively stable, in both scope and order of presentation.

The one thing that Libra would like students to get from the course would be the ability to think through a concept and understand it, rather than just memorizing a procedure. Libra emphasizes to students that moving up a notch on Bloom's taxonomy scale would help them to solve problems more easily. Memorizing equations would not be necessary, because understanding the concept is the key. A difficulty for students in Libra's view is translating words into mathematical relationships. During the interview, Libra offered several examples of good multiple-choice questions that are easy once students begin to think a question through.

Another topic Libra mentioned several times as valuable for students was the joy of science - that it is an important thing to cultivate. Part of the fun of chemistry is going into the lab and doing something interesting and possibly new.

In order to help students achieve the level they need to get to in the class Libra does a lot of problems in many different venues. There are quizzes in the testing center and problems done during lecture, sometimes by individual students. I-clickers have been valuable for Libra partly for attendance, but more for getting students to work through the problems. Libra will ask individual students, even in a large lecture, to come to the front and explain the logic of a problem. Confident students will come forward and serve as icebreakers for the rest of the class who see that they will not be ridiculed when they make errors.

Another technique this instructor uses to encourage engagement is to ask a question, then hand a microphone to a student. When the student responds, "I don't know," that student passes the microphone to a neighbor. After it has gone on a little while, Libra calls "STOP!" and the student holding the mike answers, a technique that may help build student confidence. Over the long term, Libra hopes that students can learn to analyze problems because of taking science, and appreciate the field as well as have an idea of how to work through a science question.

Libra had seen the "Life, Liberty, and Pursuit of Happiness" document and had not paid close attention to it, but agreed in general with the philosophy, which seems to Libra congruent with a liberal education. Liberal education in this professor's view



involves helping people to learn how to learn on their own which is a goal for Libra as well.

In terms of the specific scientific reasoning goals, which Libra recalled were being worked on (the interview took place as the 2011 goals were being finalized) the quantitative requirement and problem solving are two areas where Libra puts additional emphasis. The scientific process is mostly addressed in lab, but the relationship of theory and experiment comes with experiments that measure concepts discussed in lecture. The general statements about scientific method in the textbook are too general, and the topic of how chemists in particular increase knowledge, is not one that is frequently addressed according to Libra. Libra sees value in bringing in departmental research as a way of piquing student interest and will sometimes mention faculty projects or awards discussing the research topic and why the topic is of interest. An important reason for discussing such topics is to help develop curiosity, which might lead to students wanting to learn more.

Libra gave an example of attempting to motivate students who had done poorly on a test by asking them to research a name. The students came back and reported that the name was that of a Washington Redskin's football player who had enrolled in Mason and took chemistry as a step toward a medical degree. The player had no idea what the exponent meant in scientific notation, he was starting with a big deficit. By the end of the class, he had the third highest grade. He went on to do well in physics and biology and eventually got a degree from Harvard medical school. The message the professor is

trying to convey with this story is that difficulty should not be a roadblock to working at understanding the subject.

In order to get students who are not going to be science majors to appreciate the fun and interesting side of science Libra feels it is necessary to have “good cheerleaders” in front of the class. While that is not enough, it is a pre-requisite. Part of this comes from instructors who enjoy teaching and have tasted the joy of having a small part in a student’s success. Being there to help the student, talking about research, and giving back in some way are all themes for this instructor.

**Cygnus.** Cygnus has taught both lab and lecture sections of Biology. With experience teaching lecture, and, in prior semesters, labs, Cygnus has a feel for how the two parts of the course interact and is passionate about getting students interested in Biology, either as a profession or as a life-long interest.

The general education biology course is currently being restructured in order to make the labs more investigational. The current coordinator has changed the sequence of topics so that rather than beginning with cells and building toward organisms and ecosystems, the students begin labs by studying diversity in the environment of Mason and then working back into cell processes. Cygnus has rearranged the lecture to fit this model, but points out some of the difficulties of coordinating lecture and lab, time pressures when dealing with large enrollment courses, and the need to address topics completely which may mean the lecture at times runs behind lab. Cygnus feels it does not always matter, since lecture can be preparation for lab, or, since the lab book also outlines the main conceptual material, labs can serve as a lead-in to lecture material.

Whatever order the material comes in, Cygnus is adamant that students need to learn to ask questions about what is happening, “How does my body tick, how does my body work?” An example is teaching about ATP and muscles using the example of walking from one place to another. In order to understand how it is possible to use muscles, to move the entire body from one place to another, it is necessary to understand how ATP functions in muscle contraction. The goal is to bring ideas from the abstract to the down-to-earth, for example, making connections from the material to the real life function of their own bodies.

Cygnus works hard to make the material interesting. A difficulty arises when students do not engage with the material, and do not understand that what they are learning has applications to real life. An example of a useful application would be that when students visit the doctor, terminology like “osteo” or “hepatic” should make sense since they have studied them in Biology and will make the connection to “bone” or “kidney”. Basic understanding of how the body works would help them know what is going on when it is not functioning correctly.

The general education goal statements were new to Cygnus, but many are already incorporated in the class. The idea of liberty is valuable in this instructor’s opinion because education is “...a way of conquering the world” and a way of putting various ideas together to make learning experiences abound. Cygnus believes that education is also a route to open-mindedness and openness to experience.

This ties into the pursuit of happiness, which comes partly from a feeling of being able to contribute to society based on learning. To facilitate this Cygnus incorporates

material in lecture about Nobel winning experiments and how they were done. Cygnus also points out that students have been studying biology, they just don't know it. They study it when they begin to ask questions about nature or their own bodies, wondering why trees have different colored leaves, or why a particular tree is oddly shaped. Noticing and wonder are the start of the process of scientific investigation.

The scientific method is not a “cook book thing” for Cygnus, rather a process of stops and starts, advances and dead-ends. When asked if there are opportunities in lab for students to benefit from failure Cygnus responded “We absolutely have those!” and describes analyzing foods to see if they have fats or sugars and how it can be surprising when students get “incorrect” results. Sometimes they are actually doing the procedure incorrectly, sometimes the results they get are counter to prediction, but in either case, Cygnus reassures students, getting the “wrong” answer results in learning experiences in the lab. Failure to understand statistics and sample size can result in such “wrong” answers. For example, a lab that requires students to collect data such as eye color to analyze trait abundance in a population will have skewed results for the small population size of an individual lab section. But if the trait is surveyed across the entire population of biology students at Mason, the results from large and small populations can be compared.

Quantitative information is mainly a focus of labs in the view of this instructor. Major ideas in science are covered in lecture and followed up in lab. In order to teach scientific method in lecture Cygnus gives scenarios and tests them about things like

control groups, identifying the experimental group and other questions that demonstrate understanding of the process of science.

On Cygnus' wish list is smaller class size. Having 200 students means people have an incentive not to show up since they feel they will not be noticed. Size also discourages them from asking questions. Cygnus would like students to focus less on grades, but to understand the reasons why the class matters. Ideally, students would develop a hunger for knowledge and would be able to retain important concepts beyond just trying to memorize facts.

### **Course Syllabi**

I collected syllabi from all the instructors except Auriga and Aquila. Cetus' syllabus was "inherited" from a previous instructor and my analysis is based exclusively on that instructor's syllabus. Aquila's astronomy 111 course used my syllabus for the same semester as a model and while I don't have access to Aquila's version, I have analyzed my own syllabus from that semester since the goals statements were unchanged. I examined syllabi in three ways: whether goals are mentioned explicitly, whether goals mentioned aligned with Mason natural science goals for general education, and whether or not there is an indication in the syllabus of assignments that support any of the natural science goal statements.

**Goals stated in syllabi.** All of the syllabi I examined stated goals for the course in some way. The syllabus used as a basic for Cetus' syllabus lists three objectives:

- To develop your ability to comprehend, analyze, and think
- To give you
  - a better understanding of science

- an understanding of the basic concepts of geology and the world around you.
- We will investigate
  - the natural of earth materials and features
  - the process by which these materials and features are formed
  - the techniques and thought processes by which we understand the earth and its process
  - implications for earth history
  - practical aspects of human interactions with the earth

Libra states that Chemistry 211 is “designed to help the student learn the fundamental principles of some important areas of chemistry and in general remarks goes on to emphasize the importance of problem solving and of understanding concepts.

Cygnus’s syllabus (used by all Biology 103 instructors) includes the following goals from the Mason catalogue:

- ensure that all undergraduates develop skills in information gathering, written and oral communication, and analytical and quantitative reasoning
- expose students to the development of knowledge by emphasizing major domains of thought and methods of inquiry
- enable students to attain a breadth of knowledge that supports their specialization and contributes to their education in both personal and professional ways
- encourage students to make important connections across boundaries

Aquila’s syllabus, which was the one I designed and passed on, uses the same set of goal statements from the Mason catalogue and includes an excerpt from the “Life, Liberty, and Pursuit of Happiness” document, saying the purpose of general education courses is:

“...to educate, liberate, and broaden the mind, and to instill a lifelong love of learning. In conjunction with each student’s major program of study and other electives, minors, or certificates this program seeks to produce graduates with intellectual vision, creative abilities, and moral sensibility as well as skills to ensure a well-rounded and usable education.”

Orion's syllabus states in the introduction that the course is "designed to give you an overview of the solar system and the methods of astronomy. Orion mentions that a mathematical background (high school algebra, geometry and trigonometry) is necessary to do well. Subjects included are:

- Evolution of the solar system, the planets, and their properties
- The history of astronomy from prehistory to the present
- The scientific method and critical thinking
- The nature of light and the principles of telescope design

Vela's introductory material lists topics covered and states that the course sequences "...is designed to give students a working knowledge of the fundamental principles of both classical and modern physics. It also helps you to develop analytical and problem-solving skills which are critical to the learning of every well-educated student."

While I did not collect a syllabus for Auriga's course, the University 301 statement in the course catalogue states that the course covers ideas that have shaped the growth of science and says "The idea behind each major advance is treated in its historical context, with special attention to its important in mankind's understanding of the nature of the universe." The catalogue description also states "uses little mathematics."

**Syllabus statements aligned with Mason Goals** . Cygnus and Aquila use direct goals statements from the Mason web pages, though neither use specific goals for natural science. The use of quantitative and qualitative information is stressed for both Libra and Vela whose chemistry and physics courses emphasize problem solving.

Orion's astronomy course goals include a reference to learning about the scientific method and critical thinking which may align with "the critical approach of the scientific method," from the Mason natural science goals. Cetus' syllabus mentions understanding the processes of science as they relate to geology, which again might include the approach of the scientific method, or perhaps relation of theory and experiment.

The development and elaboration of major ideas in science is not stated in so many words as a goal statement, however it appears in all the available syllabi as a short list of major topics, either in the syllabus or the outline that is distributed with the syllabus.

The syllabus Cetus used lists such topics as tectonic plates and plate boundaries, paleomagnetism and continental drift. Cetus mentioned in the interview the theory of plate tectonics, and presumably during lecture discusses evidence that supports the theory.

**Evidence of assignments that support Mason goals.** The big picture that emerges from looking at the syllabi is that the courses focus on content as contained in the text almost exclusively. Each of the courses uses a textbook from a major publisher and most seem to follow the chapters sequentially. This aligns, of course with the goal of "...development and elaboration of major ideas in science," although in each case the content is primarily restricted to one particular science discipline. The exception is Auriga's course, which has a primary objective of including all the major ideas in science across disciplines.



There is some evidence of assignments that support goals for at least some of the courses. Vela does not mention relation of theory and experiment as a goal in the syllabus, but on the web page for the course for 2012, does direct students to a paper that details the process of testing theories about how the “magic mirror” demonstrated in class does its magic. The syllabus suggests further reading for interested students about theories in modern physics.

Orion and Aquila both include textbook chapters about the geocentric universe, the Copernican revolution, and Kepler and Newton. This historical sequences is used in most astronomy texts to illustrate the scientific method and to outline observations that support the theory of the heliocentric universe, so it is likely that these topics support the goal of relation of theory and experiment.

Cygnus’ biology syllabus includes both lecture and lab assignments. A genetics assignment, as mentioned by Cygnus during the interview, offers a chance for students to conduct a science investigation in lab. This supports the goal of students understanding the scientific method and relation of theory and experiment. It is possible that labs for each of these courses would have similar experiences had labs been included directly in this study

During the interview, Cetus mentioned the theory of plate tectonics, and several topics listed in the syllabus would come under the heading of relation of theory and experiment, for example, continental drift, and plates and plate boundaries. It is likely that this portion of the course does support the Mason goals of addressing the relation of theory and experiment and possibly the critical approach of the scientific method.

**Summary.** Each of these courses shows evidence of supporting at least one of the Mason goals. All seem to have a primary theme of developing and elaborating major ideas in the discipline represented by the course. The chemistry and physics courses are primarily taken by students who need to take them, not as majors, but in connection with another program that requires them and both of these seem to meet the goal of helping students use quantitative information.

A question rising from this analysis is that of desired balance. While the university lists four major goals, it appears that most attention is given to one involving major ideas in the discipline. It is possible that the scientific method and relation of theory and experiment goals are fully addressed in labs.

### **Student focus groups**

Focus group members were recruited with fliers in the Johnson Center and classroom buildings. Students who responded represented a wide range of majors, from communication to criminology, psychology, and computer engineering. The demographics of the group are summarized in Table 5. Students responded to the flier by calling my office number or emailing. Response rate seemed highest near the end of the semester, perhaps because I offered a \$15 gift card at the campus bookstore as a small incentive. While I had requested students who had completed their general education science courses, several had taken one of the required two courses and were currently finishing the second. One was a graduate student and one was actually a science major, though I had specified non-science majors. Including these students did not seem to

skew the group discussions and, in the end, provided relevant alternative points of view so are included here.

Several of the focus group members took general education science courses mandated by their choice of major, or selected from a narrowed list of options that fulfilled both major requirements and general education requirements. For example, an engineering major took physics as both as a requirement and to fill a general education science requirement. The classes taken to fulfill the requirement included physics, biology, chemistry, geology, meteorology, anatomy, astronomy, and environmental science. Focus groups included two or three students. I asked the questions in **Error! Reference source not found.** mostly in order, though sometimes when discussion veered away from one topic and to another I skipped ahead, then returned to missed questions. At the appropriate time I asked students to look at the same set of Mason goals that I gave the instructors (see Appendix A).

In general, all students answered all questions, though at times student responses were in the form of agreeing with another focus group member with a nod or an expression such as “um hm.”

These students had all passed their classes with self-reported grades varying from C to A. Although the focus groups were held in the science building where some of them had taken classes, and students knew from my email that I am an astronomy instructor, I didn't sense that they held back in criticism and comments for those reasons. They relaxed quickly in the groups and discussed the questions with enthusiasm, sometimes anger, and sometimes quite thoughtfully.

As with faculty interviews, I give a narrative for each group in this section, but summarize the information relating to research questions in the “Findings” section at the end of this chapter.

<p><b>General education science purpose:</b></p> <ul style="list-style-type: none"> <li>• What do you think is the purpose of taking general education science?</li> <li>• What did you expect your science course to include when you signed up for a science course to meet the general education requirements?</li> <li>• Can you see connections between science and your major field of study?</li> <li>• How did the course you took meet your expectations?</li> <li>• How do you think the course might benefit you in future studies and your career?</li> <li>• If you were to list the top three reasons you can think of for taking general education science, what would they be?</li> </ul> <p><b>GMUs purpose for general education natural science:</b> George Mason university lists some of the following goals for what students should learn in general education science.</p> <p>Can you point to specific instances where you learned any of these in your classes?</p> <ul style="list-style-type: none"> <li>• understanding of natural science</li> <li>• critical approach of the scientific method</li> <li>• the relation of theory and experiment</li> <li>• use of quantitative and qualitative information</li> <li>• development and elaboration of major ideas in science</li> <li>• Did your instructor ever mention any of these GMU general education goals explicitly?</li> <li>• Can you think of activities or lessons that were mainly focused on one or more of these questions?</li> <li>• How do you think that the GMU goals outlined above would be in your major field?</li> <li>• How do you think they would be helpful in other aspects of your life?</li> </ul> <p><b>Course questions:</b></p> <ul style="list-style-type: none"> <li>• What do you think the main goals of the course were from your instructor’s point of view?</li> <li>• How much of what you were taught in general education science was a repeat of what you had learned in high school?</li> <li>• How did the course you took meet your expectations?</li> </ul> <p><b>Your input:</b></p>
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Figure 3: Student focus group questions

Table 5: Student information

Code Name	Gender	Year	Major	Comments
A-2 Connie	Female	Senior	Communication – PR Minor in Tourism and Events Management	Completed Environmental and Public Policy (EVPP) 110 with B- and EVPP 111 with C+
A-3 Phyllis	Female	Senior	Psychology (minors Business and Tourism and Events Management	Completed Biology 103 with a B and Biology 104, 213 (Cell biology) and Astronomy 113 with Cs
A-4 Ellie	Female	Senior	Computer engineering	Completed Physics 106 and 161 with C and Physics 260,261 and 262 with Bs
B-1 Kent	Male	Sophomore	Economics BS	Completed Astro 111 with A-, Astro 112 with B+ and Biology 103 with B
B-2 Rachel	Female	Third Year	Psychology	Completed Geology 101 and EOS 121 Dynamic Atmosphere/Hydrosphere with A- in both
C-1- Justin	Male	Graduate	Administration of Justice	Took Cell Biology, Bio 213 and achieved B+ as an undergraduate.
C-2- Patti	Female	Junior	Psychology	Got "A"s in Biology 103, 104 and University 300 (great ideas in science).
D1- Cathy	Female	Sophomore	Criminology	Achieved C in Bio 125 and B+ in Bio 104
D2- Heli	Female	Junior	History	Took Environmental Science and Public Policy 110 achieving B- and 111 achieving B+
E1 – Casey	Male	Sophomore	Computer Science	Enrolled in Astronomy 111, 112, 113,114, And Geology 101 and associated lab
E2- Bethany	Female	Senior	Biology	Achieved B in Chemistry 211 and A in Chemistry 212, also took Bio 124 and 125

E3- Paula	Female	Senior	Psychology	Achieved B in astronomy 111/112 and A in Biology 103 and lab
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Note: I did not assign the A-1 packet since the student to whom I assigned it did not come to the focus group meeting. Names are pseudonyms that I assigned to hide identities of respondents. The reports of gen ed science classes taken and grades are self-reports done just before the focus groups and may not always be accurate as occasionally a student could not remember course numbers or exact grade.

Table 6: Courses taken by students in focus groups

Course name and number	Brief description	Restrictions
Astronomy 111/112	History of astronomy, evolution of the solar system, properties of planets, scientific method, critical thinking, nature of light, and principles of telescope design.	Not for physics majors
Astronomy 113/114	electromagnetic radiation, stellar evolution, interstellar medium, galaxies, cosmology, scientific method, and critical thinking.	Not for physics majors – Astronomy 113 for Astro B.S.
Biology 103	Chemistry of life, cell structure and function, Mendelian genetics, evolution, and diversity of life.	Any major, but can't be taken after 200 level and above Bio
Biology 104	Animal (including human) structure, function, homeostatic mechanisms, organ systems, behavior, higher plant systems, and major concepts in ecology.	Any major, but can't be taken after 200 level and above Bio
Biology 124 and 125 – Human anatomy and physiology	Introduction to structure and function of body's major organ systems.	One of four courses that meets general education natural science requirement for community health B.S. Does not satisfy requirement for COS or CHSS and not available for biology major credit
Biology 213	Introduction to cell chemistry, metabolism, and genetics.	For science majors and preprofessionals in life sciences.
Chemistry 211 and Chemistry	Basic facts and principles of chemistry, including atomic and molecular structure, gas laws, kinetics, equilibrium, electrochemistry, nuclear chemistry, and properties and uses of the more important elements and their compounds.	Credit will not be given for this course and CHEM 103, 104. Students majoring in science, engineering, or mathematics should choose this course sequence.

EOS 121 Dynamic Atmosphere and Hydrosphere	This natural science lab course is a systematic study of weather, climate, energy, and hydrologic systems viewed from a geospatial and global perspective. We will study the spatial distribution and relationships of the Earth's climate and hydrologic systems to other Earth systems, as well as the processes driving and changing them, including energy, climate, weather, and water resources.	First course in sequence that is one choice of two possible sequences for Global and Environmental change B.S.
Environmental Science 110 and 111	Studies components and interactions that make up natural systems of our home planet. Teaches basic concepts in biological, chemical, physical, and earth sciences in integrated format with lecture, laboratory, and field exercises.	One of two semesters of environmental lab science that fulfills general education science requirements for non-science majors. Can be taken in any order. One of two sequences that can be chosen for Global and Environmental Change B.S.
Geology 101	Covers Earth, processes that operate within Earth and on surface, and human interaction with Earth. Topics include minerals, earthquakes and seismology, isostasy, igneous processes and rocks, paleomagnetism and plate tectonics, weathering, mass movements, rivers and streams, groundwater, glaciers, and marine processes.	
Physics 160 and 161 Lecture and laboratory	First semester of three-semester, calculus-based introductory physics sequence, Mechanics. Experiments in mechanics, including techniques for recording, graphically and statistically analyzing, and reporting data.	designed primarily for science and engineering majors.
Physics 260 and 261 lecture and laboratory	Waves, electricity, and magnetism. Experiments in mechanics, electricity, and magnetism, including techniques for recording, graphically and statistically analyzing, and reporting data.	Prerequisites PHYS 160 with grade of C or better (2.00)  Corequisite MATH 213

Physics 262 and 263 lecture and laboratory	Thermodynamics, optics, and modern physics. Experiments in optics and modern physics, including techniques for recording, graphically and statistically analyzing, and reporting data.	Prerequisites PHYS 260 with grade of C or better (2.00)  Corequisite MATH 214
University 300 Great Ideas in Science	Nontechnical introduction to ideas that have shaped the growth of science, from the building of Stonehenge to modern theories of the Big Bang. The idea behind each major advance is treated in its historical context, with special attention to its importance in mankind's understanding of the nature of the universe. Intended for nonscience majors; uses little mathematics.	

**Focus group A.** The first focus group was conducted with three female students, all seniors. Connie is a Communications major, Phyllis a psychology major and Ellie, a computer engineering major. Connie took EVPP 110 and 111, Phyllis took BIOL 103, 103, 213 and ASTR 113 and Ellie took PHYS 160, 260, and 262. All of the courses included labs except for the Astronomy course. Ellie took the course sequence that is required as part of her computer engineering major and Phyllis took Biology courses needed for her major psychology. All achieved grades of B or C in each of the courses. All also took a course sequence, although Phyllis took two courses in addition to the introductory biology sequence.

When asked the purpose of general education science, Connie responded that she thought the idea was to take a range of subjects so they didn't focus just on the major and got experience in all areas. Phyllis agreed, but wondered why it was necessary since they had done all these things in high school. Ellie expressed the opinion that general



education science is to make sure students know the foundations of science, although in her major she could not pick, but had to take physics for pre-requisite courses for her major. Since these courses also counted as general education natural science courses, any additional science courses would have had to be taken as electives.

None of the focus group members was particularly confident about their ability to do science. Connie took the EVPP courses because she thought it would repeat what she had taken in high school and would therefore be easier. Phyllis wondered why she had to take biology again when she had had two high school courses in biology and assumed the college ones would be repetition. Ellie had taken chemistry in high school and wished after she decided on her major that she had chosen to concentrate on Physics in her IB program in high school since that was required for her major and chemistry was not. All agreed that science is hard, and that they do a lot of work in science classes for just four credits for each lecture and lab set.

When asked about how they thought the general education science courses they took would connect to their majors, only Ellie saw a direct connection. Since she uses the physics she learned in her computer engineering classes, it was easy for her to see the usefulness of studying it. Connie cited some of the skills she learned or practiced in her EVPP classes as useful for research projects in communications. Skills such as graphing and collecting data, and making presentations were things she thought would be useful in communications research. Phyllis agreed that, particularly in the research branches of psychology, being able to collect data and make graphs and tables would be useful. She

saw such skills as less useful for someone like herself since she hopes to go into therapy and counseling.

Connie stated that the instructor for the EVPP course outlined the goals in early classes. Ellie thought goals had been in the syllabus, or perhaps learning objectives, but that most people don't really read them. Phyllis agreed that teachers were specific about learning goals, but "...whether or not I caught or grasped the goals they were reaching for...questionable."

This group reported doing things in class that related to the goals and that some were covered better than others. They specifically mentioned field trips that supported development and elaboration of major ideas in science, relation of theory and experiment in labs where they gathered data to test a theory and also did quantitative work such as measurement and converting units.

Connie stated that relation of theory and experiment was covered more in lecture than lab, while use of quantitative and qualitative information was mainly in lab. Earning about scientific method happened in both. Ellie felt understanding of natural science came from lecture, but she learned more about scientific method in lab. She agreed that use of quantitative information was mainly in the lab, as was the relation of theory and experiment. Phyllis regretting not taking the astronomy lab because as she put it "I LOOVE the labs! The labs are so much fun, I like them a lot more than the lectures."

Students did not see all these courses as equally useful learning experiences. Phyllis felt she got very little from the astronomy course and was quite disappointed since it did not address the things she was interested in and was too "scientific". She didn't

elaborate on what scientific meant to her in that context, but said she had expected to learn about constellations, and star and galaxy formation and instead found the course hard to follow and concentrate on, partly, she explains, because it was a night course. She also did not find much helpful in the cell biology she took. Ellie did not find the third physics course particularly useful.

Connie thought the courses she took got her thinking about how we are made up of tiny cells, and that everything, living or dead, is made up of tiny cells. She also felt she could pick up an article in the field she studied and not be completely lost, she had enough to help put the pieces together.

All of these students agreed that the labs were the most useful and memorable parts of the courses. Phyllis felt that she might have gotten more from the astronomy class had she taken the associated lab. She felt that applying learning from lab to lecture material would have helped her understanding, since she is a hands-on person and loves labs. All of them agreed they learned more in lab than in lecture because of the hands-on experience, and because they worked in groups. They enjoyed working with people pursuing a variety of majors.

**Focus group B.** “Rachel” brought her friend “Kent” (both pseudonyms). Rachel is a junior psychology major, Kent a sophomore pursuing a B.S. in Economics. Both did well in general education science.

Rachel took EOS 121 then switched to GEOL 101 for her second science course. Kent began with BIOL 103 and switched to ASTR 111/112. Though Rachel describes herself as a high achiever and reports that she took four high school science courses, she

does not like science. Kent took very little high school science and took the biology class thinking he might go deeper into it. The course he took convinced him biology was not for him and he switched to astronomy to complete the general education science requirement.

Rachel took the weather course because it was something she had not had before and she was interested in severe weather. She learned about tornados, hurricanes and thunderstorms as expected, but was unhappy with the class for reasons that emerged during the focus group. The instructor was new to the course, primarily a researcher, had an accent that was difficult to interpret, and used a high-level textbook. In the lab, the exercises were difficult even for seniors in the class. Neither Kent nor Rachel found the science courses particularly relevant to everyday life, though both seemed to be able to talk articulately about the course content and both say they would feel comfortable reading more about the topics and could make informed decisions about issues that might arise in public life.

Both students mentioned having TAs or inexperienced teachers in lab and/or lecture and feel that should be changed. They also agreed that it would be good to offer more courses in general education science, perhaps in neuroscience for example, or something related to psychology.

Kent was able to relate what he learned in Biology to his later psychology class, and Rachel talked about knowing reasons for cold nights and the development of weather systems, though at first they dismissed connections to everyday life and/or major field of study.

Both Kent and Rachel agreed that to some extent their courses met Mason general education goals, particularly qualitative and quantitative reasoning, and development and elaboration of major ideas in science. Kent liked the focus on current events in astronomy, particularly the Hubble pictures, as well as information about extra solar planets, and other topics on the cutting edge of astronomy research. Both felt that their courses addressed the process of science, scientific method.

**Focus group C.** Two students attended this focus group over the course of about 1 ½ hours. Justin arrived half an hour before Patti, so I began with him in order not to keep him for more than the promised time. Patti joined in when she arrived, then I returned with her to the first questions after Justin had gone. Justin is a graduate student in the Administration of Justice program who took cell biology at Mason as an undergraduate. Patti is a junior psychology major who took BIO 103, and 104 and UNIV 301 (Great Ideas in Science).

Justin took only one science course, cell biology, at Mason. He had completed an AP biology class in high school and took cell biology in hopes that it would be easy, and would extend his understanding. He pointed out early in the discussion that the large lecture format and testing by multiple choice only, was quite different from his high school class where tests included essays. His high school class had also required him to write an original research paper using primary sources, a project he referred to several times during the session. In addition, he felt his cell biology class, which used the same text he had used in high school, included only a little new material, and never required him to explore a topic of interest that related to the course. While at first he did not recall

if the class had a lab, answers later in the interview indicate that he did take a lab component (which is required with the lecture).

Justin discussed possible uses for the science he learned in his profession and feels that taking environmental science might have been more useful in that regard. He is considering using his graduate degree to work for the Justice Department and speculated that a possible use for science might be in cases involving the EPA. In such a case, knowing something about environmental science would be useful, while the biology course might not be particularly helpful. He also suggested that it would help to have content knowledge to realize when someone is misrepresenting facts, but suggested that taking time to review what he already knows, or learn and research on his own would be a way to approach a case even if he hadn't taken a formal course in it. He felt that as a result of doing an essay on stem cell research in his high school biology class he could read scientific journals if necessary.

When asked about Mason goals, Justin named understanding of natural science as the primary focus of the class: for example, learning specifics about cells and organelles. Patti arrived at this point in the discussion and mentioned that she had seen a paragraph about goals in the syllabus course objectives.

Patti said that as far as Mason goals go, the scientific method was discussed in all three of the courses she had taken, two biology classes and University 300. She felt that this discussion was "remedial" as she put it. She explained "...they just tell you all the steps...you have to ask questions, you can't just make assumptions. I don't really know how in depth you can go with that." Even in lab, she reports getting a list of steps.

When asked about the relation of theory and practice, Patti reported that the word “theory” means something different in science than it does in everyday life, and gave an example saying “...the theory of evolution isn’t just like a guess.”

Justin said he felt one reason to study science is that it “teaches you to pay attention to detail...to facts and what you observe.” Patti agreed, saying that science helps you differentiate between statements and supported facts. She speculated that at the level the courses are taught at Mason there is no new material, in the sense of untested hypotheses; instead, in the classes she took they worked with information that had been tested already.

In speaking of labs, Justin emphasized that in lab, instead of learning about something, you are doing something hands on and observing results. This process of validating what you have already read is something unique about science. Patti added that at the level of general education science, they cannot do anything unique or that is part of the teacher’s own ideas because students do not have the background yet to investigate such questions.

Patti said her professor tried to connect everything, showing that science relates to many different fields. She adds that in University 300 (I believe she took University 301, but reported it as University 300); there was an effort to tie what they were learning into daily life to create long-term interest. When asked if that worked, she replied she guessed it did not, although she has always been interested in science. She feels her interest in science has come from her family who encouraged her as a child.

We returned to the subject of the relationship of their courses to high school science and both agreed they were like repeats of what they had done in high school. Patti felt that her high school had prepared her well. Since that was not true of all her classmates, college courses have had to become remedial. Her college class went into topics like cellular respiration in more depth than in high school, but some things were just repetition like “what is an atom?” or “what is an electron?” She felt there was introductory material.

Justin also felt the courses did not meet his expectations, but offered suggestions such as including an essay on a topic of student choice to make the course substantive. Patti agreed that this would make it more engaging. They both thought they might be interested in topical courses, studying something of current interest. Patti was constrained because of her major to taking specific general education science courses, but Justin thought he might have taken something topical if it had been offered.

Both suggested using resources on campus and in the area to supplement the courses. Possibilities they suggested included attending lectures, as Patti had to do for the Great Ideas in Science course, or going to museums. Justin remembered going to lectures for another course he had taken and agreed it was a good idea since so many visiting lecturers come to campus.

When asked about whether general education natural science was even necessary, Patti said the school’s reputation would suffer if it were not required, and that she would not be comfortable working at a professional job with people who hadn’t taken basic science.



Justin thought science was useful for things like understanding news reports where having a basic understanding would help. Patti felt it is important for parents to understand science so they can help their children. She has worked with children and was saddened by how many had parents who could not help them with science questions. Justin mentioned a friend with a classmate who maintained dinosaurs never existed. Patti carried the discussion on with the idea she had heard from others that scientists invented evidence about dinosaurs and made things look older than they are. Justin felt general education science does help to clear up such misperceptions about the world. Patti agreed, citing learning that creationism is just a theory, but evolution is a scientifically supported theory. She mentioned that there are several ways of knowing but science goes through the experimental way to find answers.

When asked what the most important outcomes for general education science might be Patti cited the idea that ideas must be backed up with evidence. She also mentioned the value of critical thinking. Justin felt the most important thing was being able to find information. He wanted enough knowledge so that he could find what he needed and teach others. Patti interjected that a research paper could be important in this as well.

After a brief review of the Life, Liberty document Patti suggested that science helps in the Freedom goal in that science can help people be free from prejudice and ignorance. Statements and ideas should be evaluated with evidence, not opinion.

After Justin left Patti continued, responding to earlier questions. She was disappointed that the courses she took were so much the same as high school courses and

felt it was a waste of money. Her biology class had done pig dissections, but her group had made mistakes, and she felt it would have been more worthwhile if an instructor had just demonstrated, since most of them were not going to be surgeons and did not need to know how to exert the proper pressure. She felt the pigs were expensive and not effective for learning. The lab text was also expensive, colored, on thick paper for \$40 she reported, and not reusable, she said, returning to the theme of the value of the course and its cost.

Patti also said the course was supposed to be quantitative, but that instructors tried to avoid any math. She felt everyone should be able to handle up through Algebra II at least and implied that math should play a more central role.

Returning to the theme of goals, she illustrated how the courses showed relation of theory and experiment by citing Mendel, though she says it is an overused example. She felt University 300 was a good class for people who were not interested in science. While it was also repetitious at times, she had not seen some of the material recently and mentioned that in that course the instructor made connections to other disciplines.

She thought the syllabus mentioned goals and objectives, but felt most people skipped over reading them. She thought the Great Ideas course might be a starting point to develop a test to allow students to test out of specific topics.

**Focus group D.** Two students joined Focus group D, Heli, a junior history major with an electronic journalism minor, and Cathy, a sophomore majoring in criminology. Heli took EVPP 110 and 111 and Cathy took BIOL 125 and BIOL 104 at Mason. These students had mixed feelings about their courses, in some cases having what sounded like

enjoyable and enriching experiences and in other cases doubting that the courses had relevance to anything they would ever do and wondering why the university requires them to spend the money and time on them.

Both seemed to have reservations about whether or not general education natural science was necessary. Heli stated that she thought the purpose was to “understand how the world works scientifically” while Cathy said she thought the university needed to make sure students had “gotten a basic idea of science and the real world” in high school.

Cathy had begun college as a nursing major and decided to switch as a direct result of taking Anatomy (Biology 125) which she described as horrible and not at all what she had expected after taking anatomy in high school. She described herself as a good student and went into the course thinking that it would not be a problem to learn the material, but was overwhelmed by the amount of memorization required.

In spite of their doubts about whether the courses were worthwhile in the long run, both pointed to ways they had learned that were consistent with Mason general education goals. After reading the Mason learning goals for general education science, both Heli and Cathy reported having done things in science classes, mainly in lab, that related to the goals. Heli described being able to learn lecture material from reading, but since she doesn't have access to lab materials, found the labs intriguing, and a good way to get a deeper understanding of the scientific methods. She also described knowing about the scientific method as useful for researching in other fields.

Neither remembered specific mention of the Mason goals, although Heli thought it had been in the syllabus. She was able to point to several specific examples of carrying

out the process of science in the lab in her environmental science course. They had added substances to samples of pond water and compared them over time to control samples to see what factors changed and then had written a report based on the experiment.

Cathy was taking a global community health class which involved working with data and organizing it, a skill that she said transferred from her science classes. Heli said that in the labs there was an emphasis on quantitative and qualitative information with data and graphs or charts in many, if not most, of the labs. In biology class, Cathy had done an investigation relating experiment and theory that using carbohydrates, fats, and lipids and adding chemicals that might break each of them down, then putting them in an incubator and checking them after two hours to see what had happened. The class then analyzed what had happened and why, another example of the scientific process.

When pressed, both found links to their major fields, Heli saying knowing something about, for example, earthquakes, might be useful to her as a journalist. She felt that she would have an idea of where to begin to get background material. Cathy felt that in biology she learned about the brain and how it works, which touches on things she was studying in criminology. She mentioned the value of forensics and science in solving crime.

Cathy noted that the quantitative and qualitative goals would be helpful in doing criminal investigations. She made a connection between pulling out relevant data and compartmentalizing it in science, then looking at the whole picture again with those categories in mind and drew an analogy with the same process in criminal investigations.

Heli could see how understanding science, and examining how experiments and data work together, as valuable for her history major. She mentioned specific diseases and discussed how being able to read scientific documents and journals would be useful, something she had learned to do in environmental science. In particular, she mentioned learning what an abstract was because of reading primary source material in her science class. Cathy also mentioned reading primary source material for a paper she wrote in anatomy.

Both offered examples of practical uses for the courses they took. Heli felt she might be able to garden or do something involving digging in the dirt after taking environmental science and Cathy remembered learning to take blood pressure. However, neither offered up other concrete examples nor did either mention being able to talk knowledgably about science.

Heli described her teacher as passionate about the subject saying she apparently had a goal of passing on a love for environmental science. The instructor made connections to the real world and practical subjects. She sometimes talked about economics, politics, and social implications of environmental studies. Cathy felt her instructors wanted them to learn the material and to understand science as a whole so they could apply it later.

A problem with the classes that both students expressed was that they provide too much explanation of things that are self-explanatory and assign busy work that will not matter later. Cathy appreciates the classes which are mainly exam and papers, but do not require nightly homework.

A complaint from both was that labs are time-consuming and only carry one credit while lectures are worth three credits. Specifically, there were times when nothing seemed to be happening in labs, when students were waiting to take readings, for example. A recommendation was that labs be only 1 ½ hours instead of three, or that more credit be offered for lab time. They also suggested less busy work and more hands-on activities. More field trips were another strongly supported idea. Cathy said her class had yet to go outside and she would have appreciated going out to look at plants that were in bloom when they were studying plants.

Another suggestion from this group was incorporating lab and lecture together. Cathy suggested this, saying that most of the lecture could be done by posting notes on Blackboard, and that in lecture most students sleep or do Facebook or are on cell phones. She would prefer to be allowed to study when she is ready and spend more time in lab. Heli agreed saying that lecture and lab instructors often repeat material when it could be done just once. They talked about this for a few minutes and came up with a once a week lecture and more lab time in order to allow for field trips.

Heli cited a history 300 class where students were assigned a cemetery to research and were responsible for finding information about families buried there and for searching historical documents in the local area. Doing something like that in a specialized science class appealed deeply to her.

Topical courses intrigued both of these students. They thought it might be possible to design a course that would appeal to and be relevant to people in different majors or with different interests. Among the specific suggestions they offered were

topical courses on medical disorders, marine biology, or integrative power plants. As Cathy put it, “If you want people to be really passionate about the classes then you need to make classes that people can get passionate about.” When asked what they would do if they really could remake the general education natural science curriculum they suggested courses that investigated the supernatural - whether or not it existed - the possibility of aliens or “cryptic zoology” or some such course that would interest students. On a slightly more serious side they mentioned studying planets and finding out why Pluto is “left out,” or finding out about solar flares and black holes.

At this point, the students were obviously letting their imaginations and interests loose, but both felt they could productively study topics that, while unrelated to major or profession, are just interesting to them. They suggested the purpose for such a course might help them distinguish fact and fiction.

**Focus group E.** Paula, a female, senior psychology major; Casey, a male, sophomore, computer science major; and Bethany, a female, senior biology major, made up the last focus group conducted in Spring 2011. Paula had taken ASTR111/112 and BIOL 103. Casey had taken, or was in the process of finishing, ASTRO 111, and 113 and GEOL 101 along with the labs. Bethany had taken CHEM 211, 212 and BIOL 124 and 125.

While I had originally intended to limit the focus groups to non-science majors, it was informative in this case to have the perspective of a Biology major who was required to select general education courses that would complement her major.

When asked about the purpose of general education this group concentrated on the idea that general education is required in order to produce well-rounded students and to give students a chance to experience a course that they might find interesting enough to major in. In addition, as the discussion progressed it appeared that Casey and Bethany had some real concerns about the level of the general education science courses and the difficulty of sorting out which of similar sounding courses would be the best for them.

Bethany stated that everyone should have a basic understanding of biology, and Paula liked it that in biology studying genes gave insight into what goes into making a person.

The three students had different areas of concern. Bethany was unhappy at how her science courses had made her dread and dislike science, particularly chemistry. She was particularly unhappy about the level of the courses she was required to take, kept coming back to her impression that the courses were difficult, too full of information, and required too much memorization. She was also concerned about the assumption of a level of preparation in high school that she felt not all students had the opportunity to get. She also talked about the perception that Anatomy and physiology is a “weed-out” course, which she found frustrating since it is listed as a general education course. Making the course difficult to eliminate people from higher-level follow on courses put a great deal of pressure on students, which inhibited learning she felt. Paula offered another second hand example of a friend who studied constantly for the anatomy course, memorizing bones and other structures.



On the other hand, Paula was positive about the biology class, which was similar to what she had taken in high school. Casey's views on what general education should be most closely mirrored the university goals for Mason, but he did not feel the goals were reasonable, or at least did not feel they his natural science courses met them. Paula mentioned the intimidation factor in large lecture classes, though in her large enrollment biology class she felt she could talk to the teacher. She also mentioned the value of working in groups in the lab.

One area where there was general agreement was that catalogue descriptions do not adequately explain differences among courses. An example was in physics where the difference between college (algebra based) and university (calculus based) physics was not clear to these students.

Two of this group took courses their major departments listed as fulfilling the general education requirement. Computer science B.S. candidates must take twelve hours of lab science and the department supplies a list of courses that will satisfy the requirement. Not all of the courses that meet university natural science general education requirements also meet degree requirements for students in some majors. Bethany's biology degree program was another example of a major with prescribed general education courses in natural sciences.

Bethany was particularly vocal about the difficulty of the general education courses in natural science, stating that they were the hardest classes she had taken, more difficult than courses in her major. Memorization was one of the issues, and she felt that was the key to her difficulty in anatomy and chemistry courses. Casey offered an

anecdotal account of a friend who found general education biology difficult and nearly failed due to the emphasis on memorization. Paula also offered a second person story about a friend who took a biology sequence and got poor grades. She also thought her astronomy course was hard because she did not get expected feedback about whether her answers were right or wrong. Paula said she left astronomy more confused than she had been when she started, and Bethany stated she had gone from loving chemistry to hating it.

All three took issue with the idea of grading on the curve. Bethany said that in her chemistry course students memorized and still failed tests, but then the instructor curved grades so a failing grade was actually passing. She questioned whether much learning was going on.

Paula said that she remembered learning how to read a textbook in middle school. Bethany said that, even as a science major, she has no idea how to read a science textbook. She looks for information she needs (presumably to answer questions) and leaves out the rest and still ends up feeling bombarded by information.

For Bethany and Casey there was limited selection allowed for natural science general education since their major fields had science requirements that did dual duty, supplementing the major and serving as general education natural science courses. Casey, pursuing a bachelor of science in computer science, was learning to do computer modeling and needed something to model. Since he sees the primary focus of his field being using computers to solve problems, the source of the problem could be anything from weather models, to protein folding. Learning enough science in a particular

discipline, he felt, could be a way to open doors to doing something similar after graduation.

Bethany thinks that in all the science courses she has taken from high school on there has been an emphasis on the scientific method. The labs have demonstrated the relationship of theory and experiment, making a hypothesis and testing it. She stated this happens primarily in the lab part of the course. A hypothesis is given to the students who then follow a procedure to test it. All of this group agreed strongly with Bethany's observation that creativity is limited. Casey mentioned that labs come from a book that prescribes what to do. He did not like the idea of presenting the scientific method as a checklist, and the group agreed that it was always taught that way. Bethany pointed out that the labs are mainly taught by graduate students who are held to a rigorous standard and are afraid to deviate from the schedule.

As a group, they agreed that goals had not been explicitly mentioned in instruction, though they thought that broadly outlined, generic goals for the course were usually part of the syllabus. This group interpreted quantitative and qualitative reasoning as math and concepts. Paula felt both were important parts of her Biology class and cited the Punnett square as an example of a quantitative problem.

Casey stated that he felt goals for general education courses should be different from courses that are part of a major. The level of understanding necessary is different in his opinion. Depth is necessary for a major in the subject, where for general education he felt that breadth mattered more. This goes along with the earlier statements that general

education itself is an attempt to broaden the education of students and help them understand topics outside of the major.

These students agreed that preparation matters for many of the general education natural science courses. Because some of their classmates had more extensive preparation, they had an edge over those who had not taken the courses in high school. Paula pointed out that it is the same with music, that you need to learn it early or you are too far behind to catch up, or at least it will not be easy to catch up.

After giving the group the Life, Liberty and the Pursuit of happiness document to read, all three expressed surprise that these were goals of general education at Mason. Paula seemed to sum up the group response when she said, “I never, ever thought that this was the reason.” Bethany’s tone became bitter when she discussed her lack of a background in physics and decided not to take a physics course because she had heard horror stories about the difficulty of the subject. As she put it “That’s not happiness, that’s not learning, that’s not being comfortable, I’m scared.”

Casey went into detail talking about his own experience of checking boxes to fulfill requirements, and feeling that too many boxes made it hard to think about the courses as a necessary part of developing a well-rounded education. He mentioned that people take college level courses in high school to get out of general education requirements and get on with their major field and study. It defeats the purpose he thinks, since he sees these courses as necessary to learning how to read and write well, and in the case of science, learning to think in precise and methodical ways. He said “Science isn’t a box to check, science is a way of thinking and so if I were going to say that you would

want to, you know, change anything, honestly, frankly I think that the whole gen ed system should be revamped.” This statement drew strong agreement from Paula and Bethany. Casey went on to say that, his recommendation would be to make the system more transparent by careful outlining what the courses include to make it simpler to choose the proper course. Bethany agreed that it is not clear how one level of Biology differs from another since the course descriptions sound so similar. Casey seemed to be saying as he went on that there should be general education requirements, but more flexibility in what students can choose. This may come from the fact that as a Computer science major he has a short list of possible natural science courses that fulfill both major and general education requirements. Paula mentioned a list of general education courses that is available on the web, but hard to find.

In response to a question about how the students would revamp general education natural science, Bethany suggested that all students should get a little of everything on a basic level and that the courses should stay general education and not be part of the major. General education in any of the sciences should be accessible to all regardless of prior background in science or major. She would leave out math and design the courses so people would be comfortable studying the subject. Casey agreed that some kind of survey of science course would be enough for most people who are not going into technical fields. He would include understanding science, the scientific method and, most importantly, critical thinking “which is what science is all about when you boil it down.” He feels that would be enough for most students to fulfill the purpose he sees of general education courses as ways of expanding student's horizons.

This group was uncertain about whether topical courses could meet the goals of general education. Casey felt that the necessary level of background learning might be too high for non-science majors and Bethany reiterated that all general education courses should stay at a basic level.

A question about how to revise the goals for natural science led to a long discussion of what the courses currently require and do not require in particular the level of math expected. The discussion eventually centered on the idea that, as currently taught, everything is prescribed. Casey suggested have a course in “exploratory science” where students could look at something and ask “why?” questions. His suggestion is to incorporate something along the lines of a science fair project where students could go deeply into a question to explore it. Bethany mentioned a book called “Exploring Life Sciences” that was readable and interesting, but did not relate to classes she had to take and wished that she could have had a course along those lines.

Overall, this group focused on disappointments they had experienced in general education. Only Paula, in her introductory biology course, seemed satisfied that the course had been what she expected and was a good learning experience. Bethany, who was most negative throughout, mentioned that she had dreaded coming to the building when she found out the focus group would be in Science and Tech I. Of them all, Casey came closest to holding a view of what general education science should be that matches the Mason statements the group read. Nevertheless, all of the group seemed to agree that their courses were not meeting most of the goals.

## **Findings**

In this section I will summarize findings from each of the three parts of the case study, institutional goals, faculty interviews and student focus groups.

**Summary of institutional goals findings.** Many of these goals fit under the broad headings of science process, science content, relationship of science and society, critical thinking, and skill development. While many of these overlap somewhat - skills are a necessary part of the science process for example - I think it is useful to sort them to try to identify primary emphases in these programs.

I define science process as including goals that address how science functions, its approach, methods, and techniques. In some cases the goals are presented in a passive, “learning about” manner, and in some cases a more involved “learning by doing” style. Both are included under process, but how they would be taught in an aligned system would probably be quite different. In general, I have tried to sort goals independently of how they may address teaching method and style since there are numerous approaches that might support each of the goals. When necessary I have broken down complex goals statement into component parts and counted them separately. Some institutions have streamlined goal statements that are easy to categorize, others have long lists of competencies and outcomes. If several statements address goals in the categories I have outlined, I have counted them only once.

Science content goals put emphasis on learning a body of knowledge. In the imagery of education as a building, these are the bricks and boards of science. They will be present in every science course, but some programs put more emphasis on a baseline set of science knowledge for all educated citizens.

Science and society goals involve a wide range of possibilities, using science to address societal issues and the mutual shaping of science by society and society by science and technology would fit in this category.

Critical thinking includes goals for thinking skills that could potentially be applied in many contexts, not just in understanding science. I have included here goals that expect students to evaluate science information in the media, or to distinguish science and pseudoscience.

Skills are typically laboratory skills or math skills. Since I have put critical thinking in a category of its own, skills in this analysis are primarily concerned with using tools, whether physical or mental.

Affective goals include goals that address such things as student appreciation of science and confidence that they can understand it or make informed decisions.

Broadening goals are those that state in some way that the purpose of general education science is to extend and widen the student's view of the world and understanding of processes and interrelationships. Table 7 is a tabulation of these goals by type for the surveyed institutions.



Table 7: Summary of goal types by institution

	Process	Content	Science and society	Critical thinking	Skills	Affective goals	Broadening
Mason – pre-2011	x	x		x	x		x
Mason – 2012	x		x	x	x	x	x
Macalester college	x			x	x		
University of Hawaii Manoa	x			x		x	x
University of Kentucky	x		x	x	x		x
Carleton College	x		x	x	x		X
Michigan State University	x	x	x			x	
University of Colorado	x	x	x	x	x		X
James Madison University	x		x	x	x		
Columbia University	x	x	x				
Arizona State (Tempe)	x	x	x				X
Cloud Community College	x			x	x		
Virginia Tech	x		x	x	x		
Old Dominion University	x	x		x	x		
Virginia Commonwealth	x	x	x	x			
Northern Virginia Community College	x			x	x		

It is interesting that all of the schools had goals relating to science process, while half had goals that could be construed as a focus on content. Presumably, the content goals would be more likely to be part of specific course goals, rather than broad institutional goals for specific content, though Arizona State includes a specific, though broad, content goal involving matter and energy in living and non-living systems.

While broadening perspectives was specifically listed in some form for six institutions, it might be a safe assumption that a goal of broadening student experience with various disciplines outside of the major is an important, if unstated goal, of most general education programs.

Before adopting new goals in Fall 2011 Mason and NVCC appear to be well aligned. While NVCC did not specifically include broadening of student understanding or horizons, I am making the assumption that it is tacitly understood for the most part that this is a goal of general education and a reason for including diverse disciplines in the programs. Since adopting the new goals, Mason is diverging from NVCC in a focus on science and society and on affective elements of the general education natural science program.

In regard to other Virginia institutions, Mason shares a science and society goal emphasis with JMU, VA Tech, and VCU. None of the other Virginia institutions surveyed had affective goals for general education science, so that may be an area where Mason does not align, although one of the Mason SHEV peers, Michigan State, included a goal that I classified as affective.

University of Kentucky has recently overhauled its general education program and now includes a science and society component as does University of Colorado. It will be interesting to see if this becomes a generally accepted goal for general education science at most schools in the future.

Overall, Mason goals for general education science appear to fall into the mainstream thinking on what learning outcomes are important for all students. While the new goals at Mason include a science and society component that is not always part of these programs, adoption of this goal puts Mason in good company with peer institutions and is certainly in line with science education goals of major national organizations.

**Faculty interview summaries.** As a group, faculty members were not familiar with the Mason general education goals for natural science or the “Life, Liberty, and Pursuit of Happiness” document. Some of them remembered having seen a copy of the goals, but it appears none of the faculty interviewed had mapped these goals onto their own courses, though occasionally assignment did seem to align with one or another of the goals

All faculty members took it for granted in the interview that a heavy emphasis on the specific content of the discipline was a given. In every case where I had a syllabus, assignments seemed to track textbook content almost exclusively for lecture. The two other areas that most of the faculty interviewed agreed with, and could point to, teaching specifically were “the critical approach of the scientific method,” and “the use of quantitative and qualitative information.” Libra and Vela, who teach chemistry and physics mostly for science or engineering majors, considered use of quantitative

information to be a larger part of lecture than did the others. Cetus in particular sees the use of quantitative information something best addressed in lab. A summary of where instructors indicated the Mason goals is in Table 8. A brief overview of instructor views of Mason goals and examples they gave of how they were addressed in class follows.

Table 8: Instructor views on where goals are addressed

Goals addressed mainly in lecture	Goals addressed mainly in lab
Development and elaboration of major ideas in science	Relation of theory and experiment
Provide students with an understanding of natural science	Critical approach of the scientific method
	Use of quantitative and qualitative information
<p><i>Three of seven instructors mentioned close ties in their discipline between lecture and lab.</i></p> <p><i>One does not think labs are a useful part of general education science</i></p> <p><i>One mentioned no real connection in the discipline between lecture and lab</i></p> <p><i>One was concerned about the level of instruction in labs.</i></p>	

*Relation of theory and experiment.* Aquila was skeptical about the way this is presented in astronomy, as a historical case, and wonders how much students learn from this way of presenting this idea. Orion teaches the historical case in the context of the Copernican Revolution, and also presents a modern day case, the theory of climate change. Vela and Libra both point to an interplay between what happens in lecture where theory is presented and lab where experiments are based on theory.

*Critical approach of the scientific method.* While all of the instructors agreed that this was an important goal of general education science, their approaches to incorporating it in their teaching varied. Cetus, Libra, and Vela say the main place this is accomplished is in labs, but all three pointed to ways they incorporate this teaching in at least a limited way in lecture, from direct discussion of how science is done, to examples of research going on at Mason, to a synergistic interplay of concepts in lecture and hands-on experience with them in lab. Auriga uses historical case studies to illustrate the scientific process, but does not feel students need to duplicate science experiments to learn how the process works. Orion addresses historical background of the science process in lecture and addresses a current example of how science works through presentations on climate change. Aquila stated that understanding how science works is an important goal and attempts to use hands-on exercises and examples of theory forming and testing to illustrate it. Cygnus is the only one of the instructors who mentioned testing students about the scientific method by setting up scenarios followed by questions about, for example, which would be the control group in an experiment.

*Use of quantitative and qualitative information.* Use of quantitative information should be part of general education science courses according to nearly all the instructors. Those interviewed presented a spectrum of views about how and where quantitative information and problem solving normally happens. Cygnus and Cetus place quantitative reasoning primarily in lab. Orion has chosen a text with a quantitative focus and, while being able to do mathematical calculations is not necessary to pass the course, includes quantitative material for students who can handle it. Aquila has designed an in-class

exercise to apply quantitative reasoning to problems on energy collection on Mars. Libra developed a tutoring center and computerized quizzing system because there was not time in class to do the quantity of problem solving necessary for learning chemistry. Libra also says being able to translate words into mathematical relationships is a key part of necessary conceptual understanding in chemistry and does considerable problem solving in class with student participation. Vela's physics course also involves considerable problem solving with the bulk of it happening in the recitation portion of the class, though Vela does present sample problems in lecture and feels it is critical that students see how equations are developed. Problems are a check to see if students have read and understood material. Auriga commented that thinking quantitatively is not natural for humans, but expects students to present evidence, including measurement, for truth claims about such things as the expansion of the universe.

The use of qualitative information was addressed by Aquila who would like to include discussions about current events of interest in astronomy such as whether or not Pluto should be classified as a planet.

*Provide students with an understanding of natural science.* Aquila points out that this might be a kind of thesis statement for the Mason goals and that the other ones are specifics that support it. Cetus feels that this goal is being met in the Geology course, but is mainly understanding of natural science as it relates to that particular topic. The most important goal for student learning for Vela is that students come to understand how physics explains the world. Orion sees scientific literacy as a goal and elaborates on ideas in physics when it is necessary to understand the specific discipline of astronomy.

*Development and elaboration of major ideas in science.* This goal seems to be basically unspoken as it is, of course, the source of most lecture material. However, the emphasis for most instructors is on specific discipline ideas. This seems logical since all the courses but Auriga's are discipline centered.

Auriga, with the vision of a scientifically literate population with a mental library of foundational ideas from all the major branches of science, is the exception to the one discipline approach. Cetus weaves in major ideas from other sciences when they apply to geology, and Orion includes as much physics as possible to enhance astronomy learning.

*Additional goals from interviews.* Nearly every instructor mentioned additional goals for general education science.

I have listed critical thinking in Table 7, because some of Mason's stated goals both pre- and post- 2011 could arguably be labeled a valuable part of critical thinking. Critical thinking as a goal in itself is not mentioned specifically in either the old or new set of goals for Mason general education natural science. In interviews one instructor mentioned it explicitly, and others listed goals that are consistent with critical thinking in the sciences (Brookfield, 2012). Cetus states that one of the things science does best is help students develop critical thinking by evaluating information, not just absorbing it. Classroom activities this instructor described include asking student to estimate number of volcanoes in the world, and using current events to apply what students are learning to real world events.

Auriga does not use the term "critical thinking" but mentions that employers want students who think creatively about problems and communicate well, arguably elements

of critical thinking. Libra offered examples of problems in chemistry that require some level of critical thinking to solve and Cygnus described the possibility of failure, particularly in lab, which requires students to think critically about what might have gone wrong. Vela also implied critical thinking in discussing a goal that students understand formulas, their origin and be able to differentiate similar looking ones, and know when to use each one. Vela's expectation would be that educated people could think through what science is telling them, though Vela doesn't see strong evidence that it is happening.

Many of the instructors mentioned the value of decision making with regard to science issues, either in a personal or citizenship context. Orion sees this generation of students facing difficult decisions involving science and technology and feels a responsibility to use this science course to help them prepare for making educated decisions as citizens. Cygnus believe that it is important that students master a topic to be able to contribute to society, which will also enhance their own happiness and also points out practical value for students in understanding medical advice.

Auriga frames this as being able to read the newspaper at graduation, implying that students will have the ability to understand current issues in science. Auriga later goes on to say that a goal of general education science is helping students to function as citizens.

Auriga is not in favor of formal labs for this level of education, but did use open-ended investigations in courses in the PAGE program and a current technology course for Honors. Cygnus speaks of opening students' minds to the idea that they already have



studied biology without knowing it as they ask questions about the world around them. They may not have carried the process through, but they have started the process.

The idea that a goal of these courses is that students learn to learn was mentioned by both Vela and Libra as part of a liberal education.

Auriga discusses process of science and uses historical case studies to help students develop cultural literacy. Orion also uses historical examples as does Cygnus, arguably examples of exposing students to stories that are part of our cultural heritage in science.

Libra puts heavy emphasis on problem solving skills and this is also a big part of the course for Vela. Aquila mentions communication skills as does Auriga who also emphasized the need for students to practice creative thinking about problems.

Affective goals such as curiosity and enthusiasm are included in the new Mason goal statements adopted in Fall 2011 and included in the Appendices. Aquila and Cygnus mentioned student interest and enthusiasm for the disciplines they teach, and for science in general as worthy goals. Libra values helping students see the enjoyable and interesting side of science and talks about the value of discussing departmental research to help develop curiosity and advocates cultivating the joy of science, particularly in laboratory investigations.

Vela stresses the importance of helping students see the relationship of science to everyday life, relating physical processes to the daily life of the students, and suggests that general education, including science, does indeed help people appreciate life more.

Cygnus gave a number of examples of how biology can be related to students' lives to help make abstract ideas concrete.

Vela was particularly interested in creativity and making links between art and science while pointing out that critical thinking is expressed in each differently. The two can influence each other in positive ways. Libra uses research being done in the department as a way of showing students the creative and exciting side of science.

Vela feels that general education promotes pursuit of happiness by presenting a diversity of topics that help people appreciate life more. Cygnus sees the idea of liberty, from the broader Mason general education goals, as related to the idea of learning to be open-minded and open to new experiences

Orion mentioned including an ethics statement in the Mason goals. Since participating in a democratic society requires making decisions, students should be prepared to think about the ethical implications of science and make decisions based on good science. Students should learn that they can think about science issues and that they can evaluate science choices.

Cygnus carries a heavy teaching load and feels limited by that in the amount of help and direct encouragement students get in the class. Libra has tried to solve the problem of lack of time for problem solving in lecture by instituting a tutoring center and computerized quizzes and testing.

Vela suggests that inexperienced lab instructors may not have the ability yet to help students see the deeper meanings and origins of equations they use.

Orion feels students enroll in astronomy because of interest, and the perception that it will be easy. Because it may be the last science course they take, it needs as much depth as possible since students will need to be able to evaluate science information to make good choices.

Several instructors mentioned issues related to teaching practice during the interviews. Orion endeavors to reduce distance between students and instructor and perhaps students and science with humor and a relaxed teaching style. A passionate approach to the topic helps illustrate that science is done by humans who do care about the issues they study.

Both Orion and Vela mentioned the synergistic effect of students doing both lecture and lab for understanding material

One idea brought up peripherally by Libra and Vela is that different science disciplines increase knowledge in specific ways that differ by field.

Cygnus and Auriga mentioned the benefits that come from failure and from open ended projects. Cygnus mentioned several examples in lab of how such investigations can be a moment of real learning.

**Student focus group summary.** Looking for commonalities and differences in perceptions about goals and purpose of general education science for this self-selected sample of students reveals that, not surprisingly, few remembered seeing learning goals for the courses. Two students who mentioned seeing course goals had seen them in the syllabus, with no recollection of the specifics.

Seven out of twelve students took at least one or two of the general education science courses because they were required by their major field of study, physics for a computer science major and biology for a psychology major, for example. Three students reported selecting a course because they thought it would be easy. Eight of twelve specifically mentioned that material in their courses was a repeat of high school, though most reported at least some new material. One student changed her major as a direct result of having difficulty in a pre-requisite natural science class that also counted for general education. The next sections give an overview of student perceptions about goals for general education natural science, whether the listed Mason goals were addressed in the classes, and ideas for improvement offered by these students.

*Evidence for presence of Mason goals.* As with the instructors, the two goals most mentioned most often (other than content goals) by students in the focus groups as goals they had experienced in the courses were learning about the science process, and using quantitative and qualitative reasoning.

A summary of where students mentioned experiencing the goals through assignments, lab experiments or field trip is given in Figure 4. A more detailed account of specifics that students reported about individual Mason goals follows.

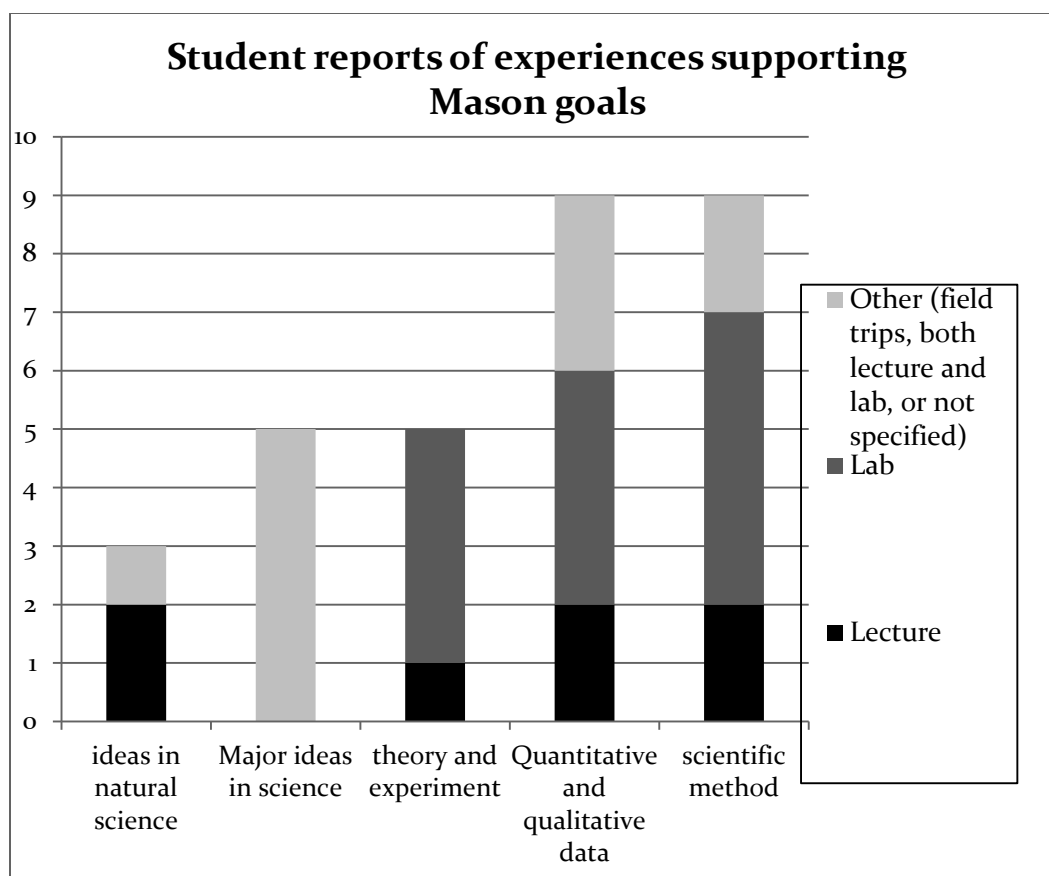


Figure 4: Student reports of experiences supporting Mason goals.

*Critical approach of the scientific method.* Bethany, Heli, Patti, and Rachel all mentioned learning about process of science by carrying out experiments in lab class. Patti discussed how science uses experimental ways to find answers to questions and backs up ideas with evidence. Because ideas in science are not based on just opinions she says, studying science helps people be free from prejudice and ignorance. Those students who mentioned the relationship of theory and experiment as an important part of the class reported that experiments in the lab support theories that may be part of lecture material.

*Use of quantitative and qualitative information.* Heli, Cathy, Connie and Phyllis, reported using quantitative information in class and outlined how skills involving graphs, charts and data handling relate to their own major fields, and might be useful in the future. When students mentioned use of quantitative information as a goal supported by their science class, nearly all pointed to lab as the venue for learning.

One student, Patti, disagreed that the use of quantitative information is an important part of the courses she took, saying that, in her view, math should play a more central role in natural science courses than it currently does. Bethany, on the other hand, favors leaving out math entirely to put the courses at a more comfortable level.

*Provide students with an understanding of natural science.* After looking at the goal statements, Justin said his classes met the goal of understanding natural science. Heli phrased it differently, saying she felt understanding how the world works is a goal of these classes. Cathy indicated that the purpose of taking natural science classes is to ensure that students get a basic idea of science and the real world in college in case they missed it in high school.

*Development and elaboration of major ideas in science.* Before reading the goal statements four of the students mentioned the idea that general education science should be about giving students a foundation of understanding of science. Patti suggested that something like the Great Ideas in Science course could be used to allow students to test out of specific topics once they had mastered them. Casey suggested a survey of science, presumably like the Great Ideas in Science course, for those who were not technically inclined.

*Student view of goals for natural science courses.* For the most part students felt the purpose of general education is to “broaden” their education or to have a well-rounded curriculum, with five of the twelve stating this explicitly before seeing the Mason goals. Focus group E agreed that another reason might be so that students could explore potential majors. Other goals mentioned, excluding the ones that align with the Mason goals, are:

- Learn to read and write well
- Learn to think in precise and methodical ways
- Learn to distinguish fact and fiction
- Learn to read scientific documents and journals
- Learn to read primary source material
- Make connections between science and real world
- Teach students to pay attention to facts and observations
- Be able to differentiate between statements and supported facts
- Be able to understand news reports dealing with science
- Correct misperceptions such as creationism
- Free people from prejudice and ignorance
- Emphasize critical thinking

*Critiques of current courses.* Students were open with critiques of the courses they had taken. Phyllis, Connie, Ellie, Cathy and Heli all felt there was too much work for the number of credits, particularly in lab. Some of the comments they made in regard to natural science courses, both content and delivery are:

- Provide different courses for general education population and majors
- Allow more flexibility for majors in computer science
- Clarify level of courses in catalogue
- Reduce level of course and don’t assume preparation that might not be there
- Courses contain too much introductory material, too much time spent on what is self-explanatory
- Gen ed science courses were harder than courses in major
- Dislike grading on curve
- Students don’t know how to read science texts that are so information packed

- Creativity limited by “checklist” approach to scientific method
- Grad students lab instructors too constrained by schedule
- Inexperienced lab instructors
- Too much memorization
- Course too “scientific” did not meet expectations
- Dissections waste of time, not much learning going on
- Lab book too expensive and not returnable
- Text too high level
- Lab exercises difficult even for majors

Suggestions for improvement. Nearly all the groups had a variety of ideas for improving the courses, ranging from restructuring to changes in content and to assignments that would aid learning.

Cathy and Heli suggest a combined lecture and lab course, or perhaps putting lecture materials on-line and meeting only once a week for lecture, leaving more time for field trips and lab experiments. In general labs seemed to be what students referred to when asked about specific instances of learning. Field trips, and experiments carried on over a period of weeks were cited as both places where students came to understand the process of science better, but also were most interested and engaged in the classes. Paula mentioned the value of group work and also the intimidation factor of asking questions in large classes even when the instructor is friendly and accessible. Other specific changes mentioned during the focus groups include:

- More hands-on activities and field trips
- Require original research project or paper
- Develop topical courses such as courses on medical disorder, marine biology, or the supernatural.
- Help students learn to read primary source material



- Make connections to the real world and practical subjects such as economics and politics
- Supplement classes with museum visits
- Attend on campus lectures that are relevant to topic
- Allow students to test out of specific topics.

## CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

Returning to the research questions after collecting data on other general education programs and on faculty and student views of natural science education at Mason will help focus the discussion of findings in this chapter and lay the groundwork for recommendations.

The original questions are:

- How do goals for general education science at Mason align with general education science goals at other institutions?
- How do goals propagated at the administrative level concerning general education natural science reach the instructors charged with implementation of the goals in courses?
- If the general education goals reach the instructors, how do the instructors incorporate them in explicit ways in the courses they teach?
- How are goals for general education science communicated to students?
- What do students and instructors see as the desired long term outcomes of studying science for students who are not majors?

I will address these questions individually, outline current efforts to reform general education science at Mason, and offer recommendations for going forward, based on findings from the focus groups and interviews at this institution.

### **Alignment of institutional goals**

*How do goals for general education science at Mason align with general education science goals at other institutions?*

For the most part, Mason goals for general education natural science align well with those at other institutions and with the broad recommendations of science education

interest groups such as AAAS, NSF and others. While the way the goals are implemented varies from institution to institution, common themes emerge. These include helping students: understand and practice the scientific process, develop skills in manipulating data, and make connections between science and society. Looking at goals alone, Mason has been in the mainstream with content, process, and skill building goals. There seems to be a trend currently toward developing natural science goals that turn attention to the relationship of science and society, an area that the goals at Mason did not explicitly address, but are included in the most recent 2011 set. Non-alignment with NVCC, which does not currently list goals for science and society and does not have an affective component explicitly in the goals, may be an issues in the future when Mason science courses include these goals.

### **Transmission of institutional goals**

*How do university goals for general education natural science reach the instructors charged with implementation of the goals in courses?*

One primary finding is that, of those I interviewed, few faculty were familiar with Mason's general education goals for natural science. Equally interesting, nearly all mentioned at least two of Mason's goals as ones they considered important in addition to the goals of development and elaboration of major ideas in science. Most of the instructors agreed that all the goals were important, but indicated that goals about the science process, relation of theory and experiment, and use of quantitative and qualitative data were addressed primarily in lab. This was borne out in data collected from syllabi which seem to be mainly content focused.

The question then is how goals reach faculty members if they are not transmitted directly. This is particularly important when institutional goals change. If the goals rise from a common culture among scientists, transmission may not be an issue, unless goals are changed and move into areas that are not part of that culture.

It is also interesting to notice that some of these courses serve as introductory courses for the major. An emphasis on a broad survey of the discipline would seem to be a given for an introductory course, particularly when it is expected that over the course of undergraduate study science majors will have time to participate in scientific investigation and will learn how to use quantitative and qualitative information and understand relation of theory and experiment. It is possible that these general education courses tilt toward preparing potential majors because these are the goals of courses that science faculty have taken themselves.

What does seem clear is that publishing goals on the institutional web page, and perhaps distributing them at new faculty workshops, is not enough to ensure that they will be consciously incorporated into courses.

### **Incorporation of goals into courses**

*How do the instructors incorporate Mason goals in their courses?*

If there is a flaw in the transmission of goals from instructors to students, it is that instructors assume that many of the specific goals that require student engagement, beyond just demonstrating understanding of content information, come in the labs. While communication between lab and lecture instructors is stronger in some disciplines, biology for example, and possibly physics, there are many ways the structure can break

down. “Step by step” labs, as the students in one of the focus groups named them, may illustrate lecture concepts or relate to theory, but on their own may not help students understand how science is really done. Explaining about processes, even exciting, current science investigations, during lecture, may lack emphasis on the realities of what has to be measured, the interplay of observation and theory, or how failure and creativity play a part in doing science.

I found good evidence that instructors in general consider goals that match the Mason goals to be important, particularly goals such as helping students learn to use quantitative and qualitative information, teaching them about the process of science, and introducing them to major ideas in at least one branch of science.. But the general feeling seems to be that time is too limited and the amount of content too great, to spend much time on these in lecture. It also seems that most lecture instructors do not measure whether students are making progress toward learning outcomes other than content mastery, perhaps because they assume the other goals are better addressed in lab.

There appears to be a disconnect between what instructors value and the way the classes are slanted, between what they want for their students and what they actually incorporate into the classes they teach.

### **Communication of goals to students**

*Are goals for general education science communicated to students and if so, how?*

The best way to answer this question is to look at student responses from the focus groups. Students were not aware of what the goals for the natural science courses were, but, like faculty, many mentioned scientific method and use of quantitative

information as important parts of the classes. They almost uniformly pointed to labs as the place where they learned these things. Lecture was a place where content was transmitted, and, perhaps, theories discussed that would later be the subject of a lab experiments. But many of the students had difficulty coming up with even one example of doing work related to these goals in lecture or lab. Memorable learning occurred during field trips for several. Two different focus groups mentioned investigations that were open-ended as part of what they most enjoyed and felt they learned from in their general education science. Students matched these experiences to goals after seeing the Mason goal statements, but had not been aware of the purpose of these activities when they were doing them.

While general education goals, including the specific goals for natural science, are posted on university web pages at Mason, as at most of the universities I surveyed, one needs to know they are there and must click through several pages to find specifics. Some syllabi include goal statements, but these can be difficult for students to examine before they have registered for the course. Some professors post them on web pages, but some post them on Blackboard where they are not available until a student has enrolled.

One student, Casey, had very explicit ideas about what the goals for natural science should be, goals that line up well with both the natural science goals for Mason and the more general, Life, Liberty document, but says these goals are not being met in the classes he took. Other students were able to point to a few examples of goals that were addressed, though none of them seemed to indicate that these topics were woven throughout the course rather than being addressed in a one-shot kind of way.

Students did, when asked directly, come up with ways what they learned in the courses might be useful to them in their majors, or in everyday life, but in general it seems they do approach natural science courses as something the university requires to make sure they have taken a range of subjects.

### **Desired long term outcomes**

*What do students and instructors see as the desired long-term outcomes of studying science for students who are not majors?*

The most commonly stated idea students gave about what these courses are for was the idea of a broad education. General education's purpose in this view is to expose students to a wide range of courses and disciplines. Reasons given were that the university wants to make sure students understand core subjects, or wants to help them make choices about what to major in. Few students seemed to think much beyond that when they considered what they would get from studying science. When asked directly, only a few felt confident that they had learned enough in a science course to discuss it even at the "dinner party conversation" level. Several expressed the opinion that science was an item to check off a requirements list, but several also had taken particular courses because they were interested in the subject matter.

For instructors, one theme that emerged from most was the desire for students to be scientifically informed citizens, able to make good choices about science policy in a world that demands complex choices. At least one instructor felt ethics should be a focus, and with the idea that students will need to make complex choices about science and its applications during their lives. Several instructors also wanted students to leave their classes energized and interested in the topic and able to use it at some level in their lives

after college, whether this means understanding what a doctor tells them, or continuing to be interested in geologic processes or astronomy.

Several students reported that their science professors were enthusiastic, even approachable, but none reported that their own attitudes toward science had become more positive over the course of instruction. Perhaps a different set of questions would have brought this out, but it was not near the surface of their thinking about science classes in college.

### **Foundational Question Revisited**

I will return briefly to the foundational question for this study and examine it in terms of what I have seen from the case study.

If a consistent underlying structure could be formulated and implemented in general education science courses, with course content built on the structure but remaining flexible and dynamic, would goals be transmitted from institution to instructors and through courses to students?

If my findings had showed that institutional goals are reliably transmitted from institution to instructors and through courses to students, it would be evidence of a consistent underlying structure that supports transmission. I maintain that interviews with instructors show, not that goals are being effectively transmitted from the institution, but that if goals are addressed at all in these courses it is because the original goals were faculty-designed. Even at that, not all faculty emphasize all the goals, and there is considerable variation in how much emphasis is put on each goal with the main thrust of the courses almost always a survey of basic content. The goals may reflect common aspirations for the group of faculty that created them, and may well reflect a common



culture in regard to perceived goals for natural science education among those who teach at the university, but do not seem to come directly from faculty structuring courses around university goals.

Alignment seems to fail most significantly at the next stage, within the courses themselves. The structure of general education science at institutions where general education natural science courses also serve as introductory courses for the major may have the effect of skewing the focus of the course toward presenting a broad array of background material at the expense of other desirable goals the individual instructors support. In addition, there is strong evidence that instructors think the goals they support, but do not strongly emphasize in their courses, are being met in the laboratory portion of the course. This may be the case, but laboratory sections were not included in this study and remain an unknown. My perception as a lab coordinator is that, while some lab exercises may be structured in a way that would address at least some of the goals of general education natural science, in the main they are designed to support lecture material. Taught by Teaching Assistants new to teaching and unaccustomed to labs that do not have a fixed endpoint (measuring a known spring constant, or confirming classification of rock samples, for example) the deeper, goals oriented side of the lab may be missed.

Finally, students do report having done activities in lab, and occasionally in lecture, that support each of the university goals to some extent. This seems to be highly variable by course and, again, may be more reflective of the lab experience than of lecture.

In short, there is some transmission of goals, but it is likely that this is due to cultural values among scientists rather than intentional shaping of courses and their corresponding lab sections.

### **For further study**

An important follow-on to this study would look in much more detail why there seems to be a disconnect between what instructors most value for their students, perhaps summarized by enabling students to make informed decisions about science, and what actually seems to be the primary emphasis, covering a large body of content in a single discipline.

As I looked at my own syllabus for Astronomy 111, my reference for Aquila's course, I realized that although I am passionately committed to helping students enjoy, develop confidence in, and understand the process of science, my syllabus too reflected primarily a content focus. What I value most I gave only a passing nod to in practice.

It will be important to see if the newest Mason goals for general education natural science will be incorporated into existing classes, or made a central part of new ones. The current study would seem to indicate that it cannot be assumed that goals will reliably percolate through the system without some changes in structure.

A very important study would be to survey adults who have gone through Mason's program of general education natural science. It would be useful to ask questions about current science topics and whether graduates feel adequately prepared to understand and make choices about issues of energy use, sustainability, and stem cell research, to name a few.

There are a number of directions for further research into alignment issues at Mason and at universities with similar structures for general education natural science. The Office of Institutional Assessment will sponsor an assessment of these courses soon, but it would be useful to do less formal assessments as well, perhaps by conducting focus group sessions with students from specific classes in order to explore how effective the classes have been in facilitating outcomes beyond content mastery.

With attempts to put both lab and lecture natural science courses fully on-line it will be critical to measure not only whether students have achieved equivalent content mastery, but whether students are progressing in mastering the broader learning outcomes for general education natural science.

### **Recommendations**

Pressure on universities over the last decade have been immense, reduced state funding, the education assessment movement, the rise of for profit institutions, the flood of students, many of whom are not prepared, the list could go on and on.

Questions about what needs to be included in general education, or whether it is necessary at all, will persist, along with the push to move classes on-line, to consider condensing degree programs to three years, and to increase course work in the major. I have come to agree with many of the students in this study, that one of the strengths of American higher education has been its focus on widening students' horizons, exposing them to various methods of thought and disciplinary practice, and rousing curiosity and interest in a wide spectrum of topics. Philosophers such as Dewey have made the case that such an education is the basis of citizenship in a democracy. While students are

exposed to a range of subjects in high school, there is still a need for them to revisit science and experience it in both more depth - by going deeper into particular topics, and breadth - seeing commonalities and differences among science fields and understanding connections through foundational concepts and theories. From listening to students it seems clear that this is not what is happening in most of the general education science classes at Mason.

A process that continues to consider these issues and more and that continually tries to get at deeply held values in order to evaluate proposed change, something along the lines of Argyris's double loop learning may be necessary to make change real and lasting, rather than superficial and transient. One comment I heard more than once during the process of selecting new goals for general education natural science was along the lines of "we did this all before," referring to changes made two or three decades before. Avoiding change for the sake of change, but making sure that there is space and opportunity for needed change, seems critical as the world, the institutions, the faculty, and most important, students, change and have changing needs.

General education programs generate large numbers of FTEs for departments, but it is possible that these courses may be given less oversight and fewer resources than courses within the major. There is certainly a trend toward large enrollment general education classes in natural science at universities across the country. After all, students in general education take one or two courses in science and then move on, and there is little incentive on the part of departments to assess long term outcomes of the courses.

And yet, as so many of the interviewed faculty pointed out, students need a level of science understanding that will enable them to make wise choices about science issues throughout their lives. Short-term solutions, involving ever larger classes with and less direct faculty – student engagement may well be short sighted if a primary purpose is to encourage interest in science and a deeper understanding of science process than students got in high school classes. Nearly all the experiences students mentioned in a positive way were small-group lab experiences or field trips, not inspirational lectures, valuable as these undoubtedly were for learning foundational ideas.

At a minimum, it is critical to know that what we want students to achieve in these courses is happening. Whether it takes faculty training, course restructuring, assessment of student preparation or some combination, it is important that we give students the best possible experience in natural science courses.

How best to do this should be not a one shot thing, but an on-going process of assessment, reflection, restructure, and re-evaluation. A university looking toward the future should find ways to simultaneously offer high quality courses and sponsor innovative and creative approaches that can be assimilated into the current programs. The faculty I interviewed were all concerned, dedicated and committed to teaching well. However, what good teaching looks like for the general education population may be significantly different than good teaching in survey courses for science majors. It will be important to think about whether there is a need to make a distinction, perhaps by offering new types of courses that would not be suitable for majors in the discipline, but would be structured to focus on big ideas and evaluation of science and its results.

The College of Science along with the Center for Teaching Excellence has made a start at developing new courses and re-slanting existing ones toward general education with a series of small grants (Curricular Innovation Grants, CIG). Courses being developed now will be in place in the 2012/2013 school year if all goes well and may provide models that can be compared to existing general education natural science courses.

At a minimum these grants, which require participation in regular meetings to discuss progress and research on assessment and curriculum, are proving to be valuable for developing a community of faculty interested in general education across the College of Science. The process of developing new goals has also brought science faculty together who are interested in curricular reform. As Wright (2005) points out, convergent units, where individual faculty feel their beliefs about teaching line up with institutional goals, have interdepartmental peer relationships, and cross-departmental discussions. Such convergence could have value beyond the general education program as faculty develop collaborative relationships for teaching and also research, including possibly educational research.

A danger with having individual faculty design innovative courses, as Ratcliff (2004) points out, is that individual efforts often wither away when the person who instituted them moves on. The CIG program includes mandatory peer group meetings with discussions of the innovations, teaching methods, and curriculum design and assessment. However, it is not always clear how to go about transferring the course to

other faculty members, or how to embed new teaching methods and course design components in established courses.

Distance education is a current major focus for the College of Science and offers opportunities to structure courses around goals and learning outcomes while at the same time increasing student engagement with the materials. On-line homework and testing options in hybrid type classes could also free some face-to-face time for investigative exercises and innovative approaches such as case study and problem based instruction.

Another approach might be encouraging faculty to do peer evaluations and participate in teaching workshops. The College of Science has made an effort to offer some training for Teaching Assistants, a program that needs to be expanded and carried on at both the College and departmental level to improve laboratory teaching. Investigative labs are particularly difficult to teach effectively. Coordinators and large enrollment lecture instructors already carry a heavy burden of grading and preparation in most departments and will need support in terms of resources they can use themselves and direct TAs toward. It also is vital to carefully consider what makes a reasonable teaching load each semester.

Experienced faculty who are willing to open their classrooms to new faculty, adjuncts, and teaching assistants might be beneficial in helping innovations to “take” rather than vanishing when their instigator moves on.

Not all change needs to happen at once, and complete reorganization is probably impractical, but it is important to find ways to incorporate change into on-going programs

to support incremental changes as well. Developing a set of general education science modules to support learning goals might be one way to gradually incorporate changes.

For example, none of the faculty members I interviewed see the process of science as a set of simple-minded steps to follow. Following Cygnus' example, it should be possible to incorporate an idea of the complex and fascinating process of doing real science into even large lecture classes by choosing topics throughout the semester to explore as processes leading to current understanding. In many cases, this might require going beyond textbook accounts and asking students to read material that tells a deeper and more nuanced story of scientific discovery.

A response to the suggestion by several students in the focus groups that field trips, or on-campus lectures might make a good addition to general education science might be to establish a series of Vision type lectures delivered by Mason's own science research faculty members. These could be widely publicized and used in live or video form as foundational material for discussions centered on Mason's goals for general education science, particularly the relationship of science to society and the process of scientific research. While not following the Columbia model precisely, these lectures would give faculty a way to broaden the scope of their courses and move away occasionally from a strictly textbook based approach to lecture.

It is important to reiterate that general education programs and assessments must be designed for the institutions they belong to, and that there will be considerable variation (The University of California Commission on General Education, 2007, p.ix). It is also important to remember that institutions change and the goals of general



education also change over time. In addition, the surge of credible disciplinary research pointing to how students learn science is reason to examine, evaluate, and even reform current programs.

**Three course restructure models.** The following paragraphs describe three restructure possibilities that I have been involved with developing. As new courses are developed and tested, it would be useful to develop some as models for future courses. The subject matter would vary by discipline, but basic structure could be modeled on samples that are made available to faculty members working too revise a course or develop a new one.

*Everyday science.* As one of a group of general education lab coordinators, I worked on a grant proposal for “Everyday Science”, an effort to students carry the science process through from original question through hypothesis and experiment to conclusion. I was one of a team that taught the course for the Honors College in Spring 2011. The course is designed to help students learn basic concepts that they missed in their high school preparation and at the same time introduce them to the process of science through student initiated investigations that are, as nearly as possible, free of traditional science lab equipment. The course was received well by the honors students who took it, but enrollment was low, partly due to being offered at 8:30 on MWF. It was designed as a team led effort to give students the advantage of expertise in more than one science field. Staffing is a problem for this course because of the need to team teach and the difficulty getting departmental approval for teaching outside the department.

This course could probably be restructured and offered within individual departments, but would lose some of the synergy of instructors from astronomy, geology and biology discussing concepts and science questions in a small group setting. This course might lend itself to the Columbia model, with university wide talks delivered by Mason science faculty followed by recitation/lab sessions, perhaps led by instructors and TAs from all the science departments, each section with a different science “flavor.”

*Extrasolar planets.* For a second CIG grant Dr. Jessica Rosenberg and I are developing a topical course on extra solar planets to be offered as a general education course in astronomy. We intend this to be a 60- 90 student studio class, with several small investigative projects, possibly including one using the school’s telescope to observe and measure a transit of an extrasolar planet. The course will be taught with one instructor, a TA and two Learning Assistants (LAs). The LAs will be paid a small stipend and will be recruited from Astronomy 111, Solar System Astronomy. LAs will meet weekly with the instructor and the TA to prepare for classes and explore teaching techniques.

*Astronomy 111 via distance education.* The third course is a distance version of Solar System Astronomy. I have offered it twice as a kind of hybrid course with students enrolled in the distance section required to take a designated lab. It has been successful in terms of student satisfaction and learning and is enjoyable to teach because of the high level of instructor/student interaction in both lecture and lab. For fall 2012 the course will enroll up to 120 in 2 sections and be delinked from lab, which may make this level of engagement quite difficult. A distance version of the lab that goes with the course is

planned for fall 2012 as well and I am currently working with the adjunct instructor who is receiving the development grant for that class.

*Summary.* All three courses have Mason goals and learning outcomes at the heart. While Everyday Science was designed before the new goals were in place, much of the focus is was on issues of science and society, and certainly on student investigations in the classroom. We also did considerable classroom work on how students can evaluate science claims by understanding the process of hypothesis, experiment, and testing results against expectations. Several of us who worked on the course had input into the new natural science goals and also helped develop the natural science assessment for the goals in place prior to 2011, so it is probably not surprising that there is considerable congruence.

**Other suggestions.** There are many more models that could be considered. A geology class that examines the geology of this area of Virginia, or an interdisciplinary course on planetary astronomy, taught by a team from chemistry, geology, and astronomy would interest students and reinforce links between science and the world. Including modules that emphasize the complex nature of scientific research and help students realize that science is full of unanswered questions would be valuable. Developing case studies to help make connections between science and ethical issues in society would also help students understand the nature of science and could be used as modules for more than one course.

Courses such as the Astrobiology course developed by Dr. Harold Geller (Geller, 2006) and currently taught only in honors, could also be offered to the non-honors

population as a way to both integrate science for these students and to whet their interest in a variety of topics associated with finding life outside the confines of Earth.

## CHAPTER SIX: REFLECTION AND AFTERWORD

### **Reflection on change process for general education natural science**

I came into the process of looking objectively at the general education natural science program by accident. I was new to Mason and was handy when the chair of Physics and Astronomy needed someone to sit in on the committee of faculty involved in creating a new assessment for the program. Through the course of several meetings it became clear that the problem that had inspired me to return to college, was the topic of this committee, “How do we know that students who are not majoring in science are getting something they need from their science courses?”

Wrapped into the committee, it was fascinating to try to develop an assessment that would show changes in students’ thinking about science across disciplines with huge differences in epistemology and method. It was frustrating when the assessment we had so painstakingly developed showed little significant change over the course of a semester, but also challenging to think about ways we could do more to help students learn something all of us considered to be a valuable part of being an educated citizen.

At the same time, I had joined a group of who were developing critical thinking modules to promote understanding in general education natural science. We used the modules as the basis for the Everyday Science course described in Chapter 5.

Developing a distance version of solar system astronomy was another opportunity to try to incorporate university natural science goals into a particular course.

Shortly after I began collecting data under the HSRB protocol submitted to do dissertation research, College of Science formed a group of faculty to study and revisit goals for general education natural science. These meetings were open to all interested College of Science faculty. I attended meetings of the group from the first one in late 2010 through the most recent meeting in early 2012.

Over the course of approximately a year I was able to listen to faculty from all across the College of Science discuss what they hold as valuable in general education science. At the same time, I was interviewing faculty and conducting focus groups with students, writing a literature review, and studying goal statements from a selection of schools. As with the faculty I interviewed, I was impressed with the level of commitment and the interest in doing the best work possible to support student learning in courses for both majors and the general population. There is no lack of desire to do well, but no consensus on how best to improve.

As a participant in the goal development group, there were times when I could contribute an insight from my own research and times when I had to re-evaluate my own pre-conceptions. In the process I have come to see the potential value of the courses we teach to the general education population, and have realized the importance of “letting students in on the secret” by telling them how the course and specific parts of the course address learning goals and are designed to help them transfer learning and skills to other areas of study.

There are numerous models for doing general education science and many efforts to improve it. I am pleased that Mason is moving along the path toward keeping science

for non-majors a valuable part of the curriculum. In Fetterman's (1996) list of pragmatic steps for evaluating programs, the College of Science has completed taking stock of where the program stands - its strengths and weaknesses, and establishing goals. The next step will be to develop strategies to accomplish program goals and objectives, followed by the final step of determining the type of evidence required to document progress.

The Curricular Innovation Grants for this year were awarded to groups and individuals with innovations in the general education area. It is exciting to hear faculty members report on what they have read, what they are planning, and what they hope to accomplish with their innovation. These courses should be a route toward tighter connections between goals and course structure.

The next major event will be the upcoming assessment of general education natural science. When the assessment is done it will be back to the start of the process, looking for strengths and weaknesses with goals in mind, and developing new strategies to reach these goals. As long as the process continues alignment will never be perfect, but should improve. The end result, if we do our job well, will be a generation of Mason graduates who can point to their natural science courses as places where they were energized not only to know about the science process, but to have the confidence that they can learn enough about science to make informed decisions that benefit the society and culture they will help to build.

## **Current Status of Mason's General Education Natural Science Program**

After the general education natural science committees recommendations for revised goals were approved, the question became how to go about implementing them in courses. One proposal suggested a tiered system with foundational courses to prepare students for in-depth investigations, followed by courses that would give students a chance to get a taste of doing science. Tier one courses would address content and skills as outlined in goals 1 - 3, possibly much as the current courses do and would usually include labs, but would not need to address the 4<sup>th</sup> and 5<sup>th</sup> goals having to do with evaluating sources and participating in scientific investigation. The new set of goals is in Appendix A.

Courses currently under development using CIG incentives include the extrasolar planet course described previously, a course that will explore the interrelationship of physical processes and culture by looking at history, geology, oceanography, and paleontology of the Mediterranean region, and revisions of current biology and chemistry courses with the new learning goals in mind. Another instructor is developing learning resources for math, and one is creating a set of modules to address science and human rights. Each of these innovations will be an opportunity for changes to the natural science program for the non-science major population.

Based on my, admittedly quite limited, reading in organizational change, I wonder if revising the goals and creating new courses will be enough for transformation of the program. There are powerful forces that mitigate against change at levels that require addressing underlying issues of values (Argyris, 1999). While the revised goals don't address teaching style and structure of courses, it is hard to imagine fully implementing



the goals, particularly number 5, participating in scientific inquiry and communicating the results, without some fundamental reworking of current courses. While this kind of change is not impossible, it may be seen as threatening. Dedicated faculty who have taught effectively and faithfully may see change as negation of their efforts.

It will be important going forward to acknowledge the value of what has been done in the past while adapting to current realities. Current research on learning points to directions for teaching that can improve learning for all students (Bransford, Brown, & Cocking, 2000), and the growing body of research on science education coming from science departments and tailored to disciplines should also give a foundation for effective change.

A factor that I had not considered as I began this project is the current push for distance education. This is both a challenge for current programs and an opportunity. Developing distance courses can be an opportunity to incorporate the revised goals into courses relatively painlessly since they courses are new and can be built from the ground up. But distance courses raise new issues about whether some of the core goals, involving curiosity, enthusiasm and engagement in the scientific process, can be addressed in a meaningful way via distance education when the enrollment in a course is too large for the instructor to interact with individual students. While I haven't conducted a formal study, the comments I have gotten on the distance version of solar system astronomy often mention instructor responsiveness and interaction as strong positives in the class. Pressure to do more with less will almost certainly mean larger sections and less

opportunity for the instructor to answer individual questions and provide meaningful feedback on student assignments.

An interesting approach currently is the idea of inverting a course, supplying video, voiced powerpoint and homework and reading assignments on-line, much as in a distance education lecture section, but leaving personal interaction to in-person teaching. Students might work on projects and problems with the instructor in the room, having prepared for class with on-line work. This would be especially interesting if it were combined with assessments to guide students to the needed modules. A student who was fully in command of Newton's laws of motion, for example, might be guided to a short overview or reading assignment as review, while one who had never seen the material might have a variety of learning materials to work through on-line.

General education natural science is on the schedule for assessment in Fall 2012. Instructors will be selected to complete a course portfolio, and will be given details about what needs to be included in time to make adjustments to their classes before teaching in the fall. The fact that instructors will be asked to show evidence that students are progressing toward the university learning goals should help stimulate reflection and intentional change to these courses.. This could very well be the start of a much stronger base for transmitting and implementing the new goals that the science faculty drafted and accepted in Fall 2011. In contrast to a multiple choice content, or even scientific reasoning test, a portfolio for a class should provide a wealth of information about where in the class goals are addressed, and with what kinds of assignments support the goals. It may help move the focus of at least some classes away from presenting a broad survey to

a structure that uses carefully selected content to address life-long learning goals that, from the interview information I collected, most science faculty are passionate about for their students. In addition, this kind of assessment may help forge tighter links between the lecture and laboratory portions of the class. If many of the new general education science goals are addressed primarily in labs, it will be important for lecture instructors to look for evidence of how that is done in labs so they can select materials for the course portfolio.

A recent suggestion by a member of the current Curricular Innovation Group is to collect focus group information from students as well. This seems like a valuable supplement to the portfolios and could provide important information about how students perceive the value of the courses they take.

Assessment, coupled with such efforts as the curricular innovation grants, the COS Brown Bag series featuring informal meetings to discuss topics like distance education, general education, and teaching large enrollment sections, and the Science Accelerator program, are opportunities for faculty to rethink undergraduate education. Mason seems to be at the start of a genuinely innovative period in undergraduate education. It is true that issues of class size, faculty preparation (particularly for Teaching Assistants), classroom space, and many more structural issues, will remain and must be dealt with, but an emphasis on improving the outcomes for students taking general education science is key to success.

Whatever the changes are to curriculum and presentation method, that these courses will be assessed, reworked, taught and assessed again, is a given. Taking this

process seriously and doing it well is vital if we really do believe that what we teach and how we teach it can make a difference, not just in terms of student's mastering a subject, but for the long-term health and strength of our democratic society.

## APPENDIX A

### General Education Assessment goals for Natural science at Mason

In general education natural science courses, students study critical approaches of the scientific method, identify the relation of theory and experiment, use quantitative and qualitative information, and understand the development and elaboration of major ideas in science. Scientific reasoning competence is one of the most important outcomes for natural science courses across disciplines. The following are the key components/learning goals of scientific reasoning\* and it should be recognized that each discipline emphasizes these goals to varying degrees:

- Students will demonstrate that they understand the ways of scientific knowing, including inductive and deductive, empirical and theoretical.
- Students will demonstrate the ability to develop and test a hypothesis. Students will demonstrate the ability to read and interpret data.
- Students will demonstrate the ability to interpret both primary and secondary sources.
- Students will demonstrate their knowledge of both quantitative and qualitative methods.
- Students will demonstrate an awareness of both the power of the scientific process and its limitations.
- Students will demonstrate an awareness of communication as an integral part of the scientific way of knowing, both between and among scientists, and between scientists and the rest of society.
- Students will demonstrate the ability to understand and value the role of science in both personal and public/societal decision-making.

*\* Revised in spring 2008.*

## **Gen Ed Natural Science Learning Outcomes (revised 7 November 2011)**

The general education natural sciences courses engage students in scientific exploration; foster their curiosity; enhance their enthusiasm for science; and enable them to apply scientific knowledge and reasoning to personal, professional and public decision-making.

To achieve these goals, students will:

1. Understand how scientific inquiry is based on investigation of evidence from the natural world, and that scientific knowledge and understanding:
  - evolves based on new evidence
  - differs from personal and cultural beliefs
2. Recognize the scope and limits of science.
3. Recognize and articulate the relationship between the natural sciences and society and the application of science to societal challenges (e.g., health, conservation, sustainability, energy, natural disasters, etc.).
4. Evaluate scientific information (e.g., distinguish primary and secondary sources, assess credibility and validity of information).
5. Participate in scientific inquiry and communicate the elements of the process, including:
  - Making careful and systematic observations
  - Developing and testing a hypothesis
  - Analyzing evidence
  - Interpreting results

NB: Lab courses must meet all five of the above learning outcomes. Non-lab courses must meet learning outcomes one through four.

# GENERAL EDUCATION

## Life, Liberty, and the Pursuit of Happiness:

a rationale for General Education at George Mason University

"Life, Liberty, and the Pursuit of Happiness" -- this ringing phrase from the Declaration of Independence makes a fine statement about the ideals of General Education (or, as it is more classically called, liberal education) as we strive to articulate it at George Mason. Let's take the three parts of Thomas Jefferson's affirmation of humanity's "unalienable rights" and see how they apply to the goals of a general, or liberal, education.

*Life.* A liberal education prepares us for life's unpredictable, fascinating journey. One sobering truth about formal learning is that no matter how many courses we take or degrees we earn, we can't master every skill and possess every piece of knowledge that we need to succeed in a dynamic world. A liberal education proposes that the highest value of the college experience is the development of our ability to continue learning, adapting, creating, and responding to an ever-changing society and career environment. A liberal education is the most practical of all, because it never goes out of date; the habits of mind it fosters help us to stay current with our careers and the life of our times.

*Liberty.* A liberal education takes its name from this part of Jefferson's phrase; the root word for both the concept we so cherish and the education we practice is the Latin *liber*, meaning "free." So this kind of education is meant to increase our freedom—of thought and action, from prejudice and ignorance. **It is the foundation stone of citizenship as Jefferson and his contemporaries envisioned that notion, a liberty built on rights, responsibilities, and respect for differences.** A liberally educated person feels free to seek knowledge and wisdom from across the whole spectrum of human experience—free to challenge the assumptions of the past (and also, after critical consideration, to accept them).

*The Pursuit of Happiness.* The liberal arts tradition provides its participants with tools for the pursuit of a happier, more engaged, more fulfilled life by putting ideals into action. The definition of happiness is personal; for some, an appreciation of "the best that has been thought and said"—or composed, constructed, painted, danced, or acted—is a necessary condition for happiness. For others, it might be an understanding of the wonder of the natural universe, the ever-changing ability of humans to create marvelous new inventions, or the complexities of the social fabric in an increasingly borderless world. For still others, it is a call to serve the community and the world in large and small ways, acting for the betterment of humanity. For most, it is some combination of the above. No matter the specifics: a liberal education offers the joy of discovery and the satisfaction of engagement with the largest questions of our time—and all time.

At Mason, we have created several ways to experience the excitement and gain the benefits of liberal education: the University General Education program; the New Century College Cornerstones; and, for a small group of outstanding students, the Honors College. Though their approaches are very different, as befits the creative spirit and diverse nature of our University, they are united in their commitment to the ideals of Life, Liberty, and the Pursuit of Happiness.

**Source:** George Mason University, Office of the Provost, general education web page retrieved on Dec. 15, 2009 from <http://www2.gmu.edu/depts/provost/gened/index.html>.

### **Natural Science**

(7 credits) *Goal:* Courses in this category are intended to provide students with an understanding of natural science. The critical approach of the scientific method, the relation of theory and experiment, the use of quantitative and qualitative information, and the development and elaboration of major ideas in science are addressed. *Required:* Two approved science courses; a course offering an overview of the principles of physics, chemistry and life sciences will be one of the two courses required of some students. At least one course will have laboratory experience.



## APPENDIX B

### Perspective on general education natural science goals at George Mason University

#### ABSTRACT

1. Describe the aims and specific purposes of the research project and the proposed involvement of human participants.

**This study will investigate general education science requirements at GMU and the alignment or lack of alignment of institutional goals and goals and objectives with views of faculty and students. After analyzing institutional goals I will interview 5 - 10 faculty members who are currently instructing general education natural science courses or who have instructed them during the past year. I will look for commonalities and differences in their views of the learning goals for general education natural science compared to stated institutional goals. I will then conduct 1 - 3 focus groups of 4 - 8 students each who have completed their general education science courses. Focus group questions will be designed to elicit their views of what general science goals and objectives were and how they see such classes fitting as part of their education and future plans. I will analyze their responses to look for areas of commonality with both instructor views and stated institutional goals. Student participants will be offered \$15 gift cards as an incentive to participate.**

2. Describe the characteristics of the intended sample (number of participants, age, sex, ethnic background, health status, etc.).

**Interviews will include up to 10 faculty instructing general education courses at GMU and will include both lecture instructors, both full-time and part-time who agree to participate. Up to three focus groups with 4 - 8 students apiece will include students who volunteer and who have completed their general education science requirement successfully. The sampled faculty and students will be over 18 and will not be selected based on gender, age, ethnic background nor any characteristic other than the ones mentioned here.**

3. Identify the criteria for inclusion or exclusion. Explain the rationale for the involvement of special classes of participants (children, prisoners, pregnant women, or any other vulnerable population).

**Criteria for faculty will be that they have instructed a general education science course for GMU between Summer 2009 and Fall 2010. Criteria for student focus group participants will be that they have successfully completed the general education science requirements for their major within the past four years. Students who are majoring in science will be excluded from this study.**

4. Describe your relationship to the participants if any.

**Some of the faculty participants may be acquaintances through employment at the same institution. Some students may have taken a general science lecture or lab course that I was teaching or coordinating.**

**PROTOCOL – Involving Human Participation**

**1. If there are direct benefits to the participants, describe the direct benefits and also describe the general knowledge that the study is likely to yield. If there are no direct benefits to the participants, state that there are no direct benefits to the participants and describe the general knowledge that the study is likely to yield.**

**There are no direct benefits to the participants.**

**General knowledge that the study is likely to yield is a better understanding of whether or not the current structure of general education science is consistent with educational goals for general education natural science classes at George Mason University. Data collected from faculty and students may help improve general education science at the institution and may point to ways to align student and faculty expectations with institutional expectations. Currently the state mandates assessment of scientific reasoning for the undergraduate population. Clarifying institutional goals and disseminating may help align learning so that it can be effectively assessed across the whole undergraduate population.**

Perspective on general education natural science goals at George Mason University  
INFORMED CONSENT FORM for Faculty participants

**RESEARCH PROCEDURES**

This research is being conducted to investigate alignment of general education goals at institution, course/instructor and student levels at George Mason University. Although the University has goals for general education natural science classes and the general education curriculum committee has approved the natural science course(es) you teach as part of the general education curriculum, it is unclear how the stated university goals are taught explicitly or implicitly in such courses, or that the university goals are conveyed to course instructors. If you consent, you will be invited to participate in a one hour interview to discuss your understanding of George Mason's general education goals and views of the role of your general education science in terms supporting institutional goals. You will also be asked your perceptions of the possible long term value of the course for students in the class(es) you teach. In addition you will be asked to complete a short survey and supply a course syllabus and outline and any other materials you feel might enhance the investigator's understanding of your views of the role of general education goals for natural science. A list of questions for the loosely structured interviews will be emailed to you in advance so you can review them before the interview.

**RISKS**

There are no foreseeable risks for participating in this research study.

**BENEFITS**

There are no benefits to you as a participant other than to further research in how general education science is carried out at George Mason University and offer you an opportunity to have a voice about general education science and its potential value to students. The benefits to the university as a whole from your participation may include a broader view of how faculty and students currently view the purpose of general education in the sciences and how university goals currently translate to practice as the school undertakes evaluation and reform of general education.

**CONFIDENTIALITY**

You will not be identified by name or identifying characteristics in published documents. Interviews will be recorded but not transcribed. Recorded interviews will be stored electronically on Rebecca Ericson's desktop computer which is password protected. Interviews will be deleted when the analysis process is complete. The interviewer will collect instructor's name, general education science class(es) taught and other possibly identifying information about course size, instructor's status (full-time, part-time, etc.) in a short survey. Each participant will be assigned a code name and the key that links the survey and interview data will be stored in a locked file cabinet in Rebecca Ericson's office.

**PARTICIPATION**

Your participation is voluntary, and you may withdraw from the study at any time and for any reason. If you decide not to participate or if you withdraw from the study, there is no

penalty or loss of benefits to which you are otherwise entitled. There are no costs to you or any other party.

**CONTACT**

This research is being conducted by Rebecca J. Ericson under the direction of Dr. Maria Dworzecka at George Mason University. Rebecca Ericson may be reached at 703-993-4588 and Dr. Dworzecka may be reached at (703) 993-9327 for questions or to report a research-related problem. You may contact the George Mason University Office of Research Subject Protections at 703-993-4121 if you have questions or comments regarding your rights as a participant in the research.

This research has been reviewed according to George Mason University procedures governing your participation in this research.

**CONSENT**

I have read this form and agree to participate in this study.

\_\_\_\_\_  
Name

\_\_\_\_\_  
Date of Signature

Version date:

Perspectives on general education natural science goals at George Mason University  
INFORMED CONSENT FORM for Student participants

**RESEARCH PROCEDURES**

This research is being conducted to investigate varying perspectives on the goals of general education natural science curriculum at the institutional, course/instructor and student levels at George Mason University. The University has goals for what students should learn in general education natural science classes, but it is unclear how the stated university goals are taught explicitly or implicitly in these courses, or how university goals are conveyed to students. If you consent, you will be invited to participate in a focus group lasting approximately 90 minutes to discuss your understanding of George Mason's general education goals and your views of the value and purpose of the general education science courses you have completed. With a group of between 5 and 8 students you will respond to a set of loosely structured interview questions centering on your perceptions of the possible long term value of your general education science courses. In addition you will be asked to complete a short demographic survey. Each participant will receive a \$15 gift certificate as a token of thanks for participating in this study.

**RISKS**

There are no foreseeable risks for participating in this research study.

**BENEFITS**

There are no benefits to you as a participant other than to further research in how general education science is carried out at George Mason University and offer you an opportunity to have a voice about general education science and its potential value to students. The benefits to the university as a whole from your participation may include a better perspective about how general education courses in natural science impact student learning and what students see as valuable in these courses as the school undertakes evaluation and reform of general education.

**CONFIDENTIALITY**

You will not be identified by name or identifying characteristics in published documents. Focus groups will be recorded but not transcribed. Recordings will be stored electronically on Rebecca Ericson's desktop computer which is password protected. Documents will be destroyed when the analysis process is complete. The interviewer will collect participant's name, general education science class(es) completed, self-reported grades for the classes, gender, age, and intended major of the participants. Each participant will be assigned a code name and the key that links the survey and focus group data and code name will be stored in a locked file cabinet in Rebecca Ericson's office.

**PARTICIPATION**

Your participation is voluntary, and you may withdraw from the study at any time and for any reason. If you decide not to participate or if you withdraw from the study, there is no penalty or loss of benefits to which you are otherwise entitled. There are no costs to you or any other party.

**CONTACT**

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This research has been reviewed according to George Mason University procedures governing your participation in this research.

**CONSENT**

I have read this form and agree to participate in this study.

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Name

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Date of Signature

Version date: December 2009

## APPENDIX C

### Frontiers in Astronomy: The search for extra solar planets

Rebecca Ericson and Jessica Rosenberg

We propose a new general education topical astronomy course tentatively titled “Frontiers in Astronomy”. Our goals with this class will be two-fold: (1) to use the exciting new discoveries of planets around stars other than the sun to draw students into studying science and (2) to apply active learning techniques and the use of undergraduate learning assistants in the classroom to improve the large lecture course experience.

**Topical approach:** The pilot course concentrates on the search for extra solar planets, a topic that is current, and of interest to the general public. In future offerings, instructors could select different topics of current interest while maintaining a similar course structure. We will base the course structure on the current learning goals for natural science. Having a basic structure in place will make it easier for instructors to include new content in future semesters while maintaining the focus on what matters beyond content. The instructor will emphasize learning goals that have broad applicability to other fields, and will structure assessments and activities around Mason’s learning goals for natural science.

**Active Learning Techniques:** Much work has been done studying how to make large lecture courses, particularly in the sciences, more interactive. These techniques have generally been shown to improve student learning in these classes. We will make use of several of these techniques for this class including Peer Instruction, online learning that is similar to Just-In-Time Teaching, lecture tutorials, and other forms of group work. Many of these things are already used in some of our classes, but putting them together in a coherent way as we build this course from the beginning should improve learning and engagement.

**Learning assistants:** The active learning techniques that have been developed are aimed at making it possible to interact with students in a large lecture class, but reaching 90+ students is still difficult. For this class we propose to use undergraduate learning assistants (LAs) to help involve the students more completely in the lecture. These LAs will help get students discussing clicker questions (Peer Instruction), will help facilitate lecture tutorials and other group work, and will be involved with online discussions outside of the classroom (Just in-Time Teaching). Face to face discussion groups led by LAs would give students a non-threatening forum for asking questions in a peer group setting.

A primary aim of this course is to improve learning and motivation while maintaining a relatively low per student cost. Projects using learning assistants at the University of Colorado

at Boulder demonstrate that it is possible to lower per student course costs by using learning assistants.<sup>9</sup>

In our case, LAs are paid a small stipend and are expected to spend approximately six hours a week helping with small group activities and investigations. Lecture time would be split, with part used for LA led group activities and some lecture and homework material moved on-line. Instructors would meet weekly with LAs to plan and prepare for the week to come. LAs would benefit from this arrangement, deepening their understanding of the subject matter even as they practice active teaching techniques in the classroom.

**Implementation:** The three credit pilot class would run in Fall 2012 with 90 students, one instructor, and 3 learning assistants. Learning assistants for the first pilot course would be paid with the grant stipend. In future semesters we hope to find other funding sources, perhaps through the College of Science accelerator program. The program could be scaled up from the pilot both by offering larger sections and by using LAs in other general education science courses.

The first group of learning assistants would be recruited from students who complete Astronomy 111 in fall 2011 with a grade of B+ or better. We would particularly like to select learning assistants who are interested in teaching, or those who are considering a science major. LAs would meet weekly with the instructor who will help them learn both the necessary science and teaching techniques to be effective in the classroom. This kind of mentoring can have long-term benefits both for the development of future teachers and retention of students in the sciences.

During the development stage, we will build a course structure centered on general education science goals, using topical material to “populate” activities and assignments. We would design the course to use current technologies for homework, quizzes, and discussion boards. A small-scale research project using a public database is one example of an activity that could be structured generally enough to use as a prototype for a variety of topics in astronomy or even for topical courses in other science disciplines.

While the course would be structured as the equivalent of a three credit lecture, students who need a total of eight credit hours of natural science might opt to combine this course with the one credit Astronomy 112 stand-alone lab, which deals with our own solar system. The lab would provide an additional opportunity for hands-on experiences in astronomy and would enhance understanding of extra-solar planetary systems for those who choose this option.

**Outcomes:** We anticipate that this course could become a model for other large enrollment lecture courses in the College of Science. Current survey courses are not always appropriate for the general education population, but merely changing content without simultaneously adjusting pedagogy to the needs of non-science majors will not likely produce long-lasting changes in learning. We need to educate a new generation to feel confident that

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<sup>9</sup> See the University of Colorado plan and reports at [http://www.thencat.org/PCR/R1/UCB/UCB\\_PR6.htm](http://www.thencat.org/PCR/R1/UCB/UCB_PR6.htm). We will use lessons learned and outcomes in that program as a roadmap for shaping this course.



they can think and talk about science, can understand current issues in science, and can make good choices, based on evidence, in diverse areas of their lives, including choices that matter at the intersection of science and society.

One particularly exciting aspect of this proposed course would be the chance to work with the LAs, potential teachers and scientists, using face-to-face and technology-assisted methodologies and effective teaching techniques. We hope all of us, students, LAs, and instructors will develop new enthusiasm for science and deeper understanding of how to learn as we explore the frontiers of astronomy together.

**Biographies:** Rebecca Ericson has taught astronomy classes in both studio style and distance education formats, and is interested in developing a general education science course that effectively incorporates GMU natural science learning goals and objectives. Jessica Rosenberg has first-hand experience in teaching with LA support at the University of Colorado, Boulder and has worked with Eric Mazur and other proponents of active learning. We plan to work together to develop the course, and one of us would teach the course in 2012.

# Everyday Science

*"The most exciting phrase to hear in science, the one that heralds new discoveries, is not 'Eureka!' (I found it!) but 'That's funny...'"*

*-- Isaac Asimov*

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## Required materials:

**Textbook:** Hazen, R. M. & Trefil, J. (2009). *Science Matters*. New York: Anchor Books.

**Materials for investigation:** Your group may need to purchase a limited amount of materials for your investigation.

**Three ring binder and section dividers:** A 1 inch binder should be sufficient with as many tabs as you think necessary to organize your work

**Calculator:** basic functions including log and scientific notation

## Course description:

This is an interdisciplinary investigative laboratory course, scaffolding three important components of scientific practice using critical thinking modules developed to help students understand measurement, scientific method, and ways to evaluate scientific claims. Students will formulate simple questions that can be addressed using the methods of science, using a problem based learning (PBL) approach. Specific problem-based investigations based on questions raised by students early in the class will be designed and carried out in small groups in carefully monitored steps to ensure that students incorporate principles of measurement, data collection and analysis and experimental design in their investigations.

## Goals and objectives:

General education science courses are intended to provide students with an understanding of natural science. The critical approach of the scientific method, the relation of theory and experiment, the use of quantitative and qualitative information, and the development and elaboration of major ideas in science are addressed.

Because this course is taught by instructors from various science disciplines, the main focus is on the scientific process with the assumption that all students have

had basic coursework in foundational disciplines in biological and natural science. Three basic areas of science are the foundation of teaching in this course:

- How big is it? - the use of measurement, scaling, graphical representation and interpretation of data.
- How do we know? - understanding the process of science by asking relevant questions, formulating testable hypotheses, designing and carrying out investigations
- Is it science? - students will learn to critically evaluate and discriminate between science and claims that are not grounded in authentic science

### **Goals**

Students will learn practices and tools of science

Students will be able to critically assess and discriminate between science and pseudoscience

Students will understand the relevance of the scientific process, and scientific tools to their everyday lives

Students will develop a sense of scale of the natural world and a better understanding of humanity's place in the universe

### **Value to student**

This four credit course fulfills the university general education requirement in laboratory science. It should help students think critically about science claims and increase their confidence as they read about science and evaluate social needs regarding science.

### **Assessment:**

**Individual writing:** introductory mini-essay: why science, weekly reflective writings, summary writing: why science revisited

**In-class Assignments** (quizzes, science flow-chart, Science checklist, science toolkits, minute papers (counts for participation),

**Group Investigations** groups will develop a science question concerning their everyday world and will develop the question into a testable hypothesis, plan an investigation, do background research, carry out the investigation and present the results to the class.

**Black Box Investigation** a combination of written and hands on activities where students will develop a method for investigating the contents of a "black box" using simple tools and complex reasoning.

**Individual Portfolio** At the end of the semester students will present an organized portfolio consisting of their individual writing assignments and in-class assignments, field notes from their investigations and other documents arranged to show how their thinking about science has changed over the semester.

Individual writing	rubric	20%
In-class assignments	various depending on assignment	20%
Group investigation	class designed rubric	40%
Black box investigation	rubric	10%
Individual Portfolio	rubric	10%

Everyday Science Course outline by week				
Unit 1: What is science and why should we understand how it works?				
Week	How Big is it?	How do we know?	Is it science?	Other pieces
Week 1	Scaling exercise Solar system (based on Earth as peppercorn) Geological timeline  Video - How big is a cell? <a href="http://www.cellsalive.com/howbig.htm">http://www.cellsalive.com/howbig.htm</a>	In-class investigation - Will ice melt faster in salt or fresh water?  "What if" questions (see What if the Earth had two moons?)	Science 101 reading on KT event - follow process on science process web	Video – Why Science? One page writing on why science - their ideas  Pre-test on "big ideas" in science.
Week 2	Data analysis for investigation 1 Gas Mileage case study <a href="http://www.sciencecases.org/gas_mileage/notes.asp">http://www.sciencecases.org/gas_mileage/notes.asp</a>	Students formulate questions  Bubble video - developing investigation <a href="http://www.youtube.com/watch?v=eV6Wh-KX3bY">http://www.youtube.com/watch?v=eV6Wh-KX3bY</a>  Second investigation (ongoing)- Sorting birds by type of food in bird feeder	Continue Science 101 activity - Henrietta Levitt story - use science checklist	Science process quiz - Tombaugh article - science cycle

Week 3	<p>Graphing exercise using data set</p> <p>Planetary data video - Powers of 10 collect and summarize data from second investigation</p>	<p>Select investigation questions by student groups</p> <p>Third investigation</p> <p>What makes bread rise?</p>	<p>Give students writing to analyze for science content using the science process web.</p> <p>Discussion of science misconceptions</p>	<p>Collect examples of science news accounts and web sites and analyze in class using checklists</p>
Week 4	<p>Famous graphs – graphs as story telling devices – H-R diagram, curve of binding energy etc.</p> <p>scale and physical parameters for living beings</p> <p><a href="http://www.sjsu.edu/faculty/watkins/longevity.htm">http://www.sjsu.edu/faculty/watkins/longevity.htm</a></p> <p>Taxonomy of a junk drawer</p>	<p>Refine question and devise draft plan for investigation – limiting variables</p> <p>Exercise on developing hypotheses</p> <p>Fourth investigation - micrometeorite contribution to surface sediments lab</p>	<p>Student led discussion of articles and web sites they have collected in portfolio for good/bad science</p>	<p>structure of the periodic table of the elements</p>
Week 5	<p>Measurements as predictors – how big could a spider get on Mars?</p> <p>What time is it? Astrolabe as a technology tool video</p> <p><a href="http://www.ted.com/talks/tom_wujec_demos_the_13th_century_astrolabe.html">http://www.ted.com/talks/tom_wujec_demos_the_13th_century_astrolabe.html</a></p> <p>Modern CO2 problem</p> <p><a href="http://serc.carleton.edu/introgeo/teachingwdata/examples/ModernCO2.html">http://serc.carleton.edu/introgeo/teachingwdata/examples/ModernCO2.html</a></p> <p>Fermi problem - How many cells are there in the human body?</p>	<p>Continuation of one of previous investigations – refine question and develop new procedure</p>	<p>Develop list of what to look for in reading about science to evaluate it.</p> <p>Reading a science paper jigsaw activity (Sedna paper)</p>	<p>Citizen science project</p> <p>Library field trip for research methods and using Zotero.</p> <p>Students will have a chance to begin researching their own topic.</p> <p>Formatting and documenting a science paper</p>

Week 6	<p>Error analysis and estimation</p> <p>Fermi problem - How many pencils would it take to draw a straight line along the entire Prime Meridian of the earth?</p> <p>Classification assessment  <a href="http://pals.sri.com/pals/tasks/9-12/Classification/directs.html">http://pals.sri.com/pals/tasks/9-12/Classification/directs.html</a> </p>	Finish investigation plans place, method, equipment, etc.	Discussion of topics from What don't we know article	<p>Analyzing data collected in citizen science project</p> <p>Design rubric for peer review of presentations for mini-conference</p>
<b>Unit 2: Science investigations in everyday life</b>				
Week 7	Systems of measurement – develop one in class and convert to standard measurements	Begin investigations in small groups	Case study on Pseudo science	
Week 8	Mapping exercise – reading, using and comparing scales	Continue small group investigations	<p>Seeing is not believing – moon illusion and others</p> <p>Optical illusions web page  <a href="http://www.michaelbach.de/ot/">http://www.michaelbach.de/ot/</a> The Same color illusion Oct. 4, 2009  <a href="http://antwrp.gsfc.nasa.gov/apod/astropix.html">http://antwrp.gsfc.nasa.gov/apod/astropix.html</a> </p>	
Week 9	Preliminary group data analysis and refined collection methods	Continue small group investigations	Analysis of historical science hoaxes	
Week 10	Science posters- using data to make a case/support findings	Finish small group investigations	self-evaluation of group projects - does investigation meet standards for "real" science	Making an effective presentation with powerpoint
Week 11	Working in small groups to present data in graphical and table form	Wrap up any loose ends in investigations	Cast study - cell phone use	In – class workshop on poster presentations plan mini-conference
<b>Unit 3: making science public – communicating science results</b>				

Week 12		Black box practical exam		Second One page writing on "Why Science ?" "Big Ideas" Posttest Portfolio Due.
Week 13		Mini-conference Presentations and peer critique		
Week 14		Unanswered questions in Science / Role playing /lobbying for funding		Portfolio review with individual students
<p style="text-align: center;"><b>Learning Goals</b></p> <p>Develop sense of scale and understanding of humanity's place in the universe  Learn practices and tools of scientific inquiry  Be able to critically discuss and discriminate between science and pseudo-science  Integrate learning in science with other areas of life</p>				

## REFERENCES



## REFERENCES

- AAC&U. (2005). *Liberal education outcomes: A preliminary report on student achievement in college*. Washington, DC: AAC&U.
- AAC&U. (2007). *College learning for the new global century: A report from the National Leadership Council for Liberal Education and America's Promise*. Retrieved on April 2, 2011 from [http://www.aacu.org/leap/documents/GlobalCentury\\_final.pdf](http://www.aacu.org/leap/documents/GlobalCentury_final.pdf).
- AAC&U. (2005). *Shared futures: Global learning and social responsibility*. Retrieved on July 2, 2009 from <http://www.aacu.org/SharedFutures/index.cfm>.
- AAC&U. (2007). *College learning for the new global century: A report from the National Leadership Council for Liberal Education and America's Promise*. Retrieved on April 2, 2011 from [http://www.aacu.org/leap/documents/GlobalCentury\\_final.pdf](http://www.aacu.org/leap/documents/GlobalCentury_final.pdf).
- AAC&U. (2010). *The quality imperative: Match ambitious goals for college attainment with an ambitious vision for learning*. Washington, DC: AAC&U. Retrieved on April 2, 2011 from [http://www.aacu.org/about/statements/documents/Quality\\_Imperative\\_2010.pdf](http://www.aacu.org/about/statements/documents/Quality_Imperative_2010.pdf).
- Aikenhead, G.S. (2006). *Science education for everyday life: evidence-based practice*. New York: Teacher's College Press.
- American Association for the Advancement of Science. (1990). *Science for all Americans*. New York: Oxford University Press. Retrieved from <http://www.project2061.org/publications/sfaa/online/intro.htm>.
- Argyris, C. (1999). *On organizational learning* (2<sup>nd</sup> ed.). Malden, MA: Blackwell Publishers.
- Argyris, C., Putnam, R. & Smith, D.M. (1985). *Action science: Concepts, methods, and skills for research and intervention*. San Francisco, CA: Jossey-Bass.
- Arum, R. & Roska, J. (2011). *Academically Adrift: limited learning on college campuses*. University of Chicago Press: Chicago.

- Beichner, R.J. (2008). *The SCALE-UP project: A student-centered active learning environment for undergraduate programs* (Commissioned paper for the National Academy of Sciences). Retrieved on Nov. 1, 2001 from [http://www7.nationalacademies.org/bose/Beichner\\_CommissionedPaper.pdf](http://www7.nationalacademies.org/bose/Beichner_CommissionedPaper.pdf).
- Blois, B.A. Jr. (1987). *The PAGE program from concept to curriculum: George Mason University's plan for alternative general education, 1981-1983*. (Unpublished doctoral dissertation), George Mason University, Fairfax, Virginia.
- Bok, D. (2006). *Our Underachieving Colleges: A candid look at how much students learn and why they should be learning more*. Princeton, NJ: Princeton University Press.
- Bourke, B., Bray, N.J., Horton, C. C., (2009). Approaches to the core curriculum: An exploratory analysis of top liberal arts and doctoral-granting institutions. *The Journal of General Education*. 58(4) 219-240. DOI:10.1353/jge.0.0049.
- Bowling, B.V., Huether, C.A., Wang, L., Myers, M.F., Markle, G.C., Dean, G.E., ... Acra, E.E. (2008). Genetic literacy of undergraduate non-science majors and the impact of introductory biology and genetics courses. *BioScience*, 58(7), 654-660. doi: 10.1641/B580712
- Boyer, J.W. (2006). A twentieth-century cosmos: The new plan and the origins of general education at Chicago. *Occasional Papers on Higher Education XVI*. Chicago: The College of the University of Chicago. Retrieved from [http://college.uchicago.edu/sites/college.uchicago.edu/files/attachments/Boyer\\_OccasionalPapers\\_V16.pdf](http://college.uchicago.edu/sites/college.uchicago.edu/files/attachments/Boyer_OccasionalPapers_V16.pdf).
- Bransford, J.D., Brown, A.L. & Cocking, R.R. (Eds.). (2000). *How People Learn: Brain, mind, experience, and school*. Washington, DC: National Academy Press.
- Brookfield, S. (2012). *Teaching for critical thinking: Tools and techniques to help students question their assumptions*. San Francisco: Jossey-Bass.
- Churchley, J. (2011). Capturing the 'plaid' moment: the use of practitioner research and student researchers in researching experiences with the arts. In P. Thomson & J. Sefton-Green (Eds.), *Researching creative learning: Methods and issues* (pp. 17-28). New York, NY: Routledge.
- Clark, D.A. (1998, Summer). The two Joes meet – Joe College, Joe Veteran: The G.I. Bill, college education, and postwar American culture. *History of Education Quarterly*. 38(2), 165-189.

- Cohen, L., Manion, L. & Morrison, K. (2007). *Research methods in education*. London & New York: Routledge.
- Dabbagh, Nada. (2002-2006) Instructional design knowledge base webpage.  
[http://classweb.gmu.edu/ndabbagh/Resources/IDKB/models\\_theories.htm](http://classweb.gmu.edu/ndabbagh/Resources/IDKB/models_theories.htm).
- Dancy, M.H., Henderson, C. (2008). *Barriers and Promises in STEM Reform*. Commissioned paper, Board on Science Education (BOSE), The National Academies. Retrieved from  
[http://www7.nationalacademies.org/bose/Dancy\\_Henderson\\_CommissionedPaper.pdf](http://www7.nationalacademies.org/bose/Dancy_Henderson_CommissionedPaper.pdf)
- DeBoer, G.E. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science Teaching*. 37, 582-601.
- Deneen, Patrick J., (2003). Invisible Foundations: Science, Democracy, and Faith among the Pragmatists. *Pragmatism, Law and Governmentality*. Paper 2. Retrieved from  
[http://scholarship.law.cornell.edu/ealccs\\_plg/2](http://scholarship.law.cornell.edu/ealccs_plg/2)
- Dewey, J. (1897). My pedagogic creed. *School Journal* 54, pp. 77-80. Retrieved from  
<http://dewey.pragmatism.org/creed.htm>.
- Dewey, J. (1897/1964) My pedagogic creed. In R. Archambault, (Ed.), *John Dewey on Education*, (pp.427-439), New York, NY: Random House.
- Dewey, J. (1902). *The Child and the curriculum*. Chicago, IL: University of Chicago Press.
- Dewey, J. (1916). *Democracy and Education: An introduction to the philosophy of education*. New York, NY: Macmillan. Retrieved from  
[http://books.google.com/books?id=8P0AAAAAYAAJ&printsec=frontcover&source=gbs\\_atb#v=onepage&q=Chapter%208&f=false](http://books.google.com/books?id=8P0AAAAAYAAJ&printsec=frontcover&source=gbs_atb#v=onepage&q=Chapter%208&f=false).
- Dewey, J. (1922/1964) The nature of aims. In R. Archambault, (Ed.), *John Dewey on Education*, (pp.70-80), New York, NY: Random House.
- Dewey, J. (1928/1964) Progressive education and the science of education. In R. Archambault, (Ed.), *John Dewey on Education*, (pp.169-181), New York, NY: Random House.
- Dewey, J. (1929). *The quest for certainty*. New York: Minton, Balch. Retrieved from  
<http://ia600306.us.archive.org/0/items/questforcertaint032529mbp/questforcertaint032529mbp.pdf>.

- Dewey, J. (1930/1962). *Individualism, old and new*. New York, NY: Capricorn Books.
- Dewey, J. (1933). *How we think, a restatement of the relation of reflective thinking to the educative process*. Boston, MA : D.C. Heath and company.
- Dewey, J. (1938). *Logic: The theory of inquiry*. New York, NY:Henry Holt.
- Diamond, R. M., & Adam, B. E. (1997). *Changing priorities at research universities: 1991–1996*. Syracuse, NY: Center for Instructional Development, Syracuse University.
- Dix, D, Miller, R., Horn, M, and Brown, D. (1999). What is Science? In Seabury, M. (Ed.), *Interdisciplinary general education: Questioning outside the lines*. (pp. 123-138). New York: College Entrance Examination Board.
- Donovan, W. (2007) Macalester College. Classics Department Oral Histories. Interview with William Donovan, Professor of Classics. DigitalCommons@Macalester College.
- Ewell,P. (2004). *General education and the assessment reform agenda*. Washington, DC: AAC&U.
- Fairweather, J. W.(2005, July/August). Beyond the Rhetoric: Trends in the Relative Value of Teaching and Research in Faculty Salaries. *The Journal of Higher Education*, 76;4, p. 401-422. DOI: 10.1353/jhe.2005.0027.
- Fetterman, D.M (1996) Empowerment Evaluation: An introduction to theory and practice. In D. Fetterman, S. Kaftarian, & A. Wandersman (Eds.) *Empowerment Evaluation*. (pp. 3–46). Thousand Oaks, CA: Sage Publications.
- Frechtling, J. & Sharp, L. (Eds.). (1997). *User-Friendly Handbook for Mixed Method Evaluations*. National Science Foundation, Directorate for Education and Human Resources, Division of Research, Evaluation and Communication.
- Freire, P. (2000). *Pedagogy of the oppressed*. New York, NY:Continuum.
- Gaff, J.G. (1999). *General education: The changing agenda*. Association of American Colleges and Universities, Washington, D.C.
- Gaston, P.L. & Gaff, J.G. (2009). *Revising general education – and avoiding the potholes*. Washington, DC: Association of American Colleges and Universities.

- Geller, H. (2005). Astrobiology as an alternative integrated science curriculum for higher education (Unpublished doctoral dissertation). George Mason University, Fairfax, Virginia.
- George Mason University Libraries. (1983-1998). George Mason University Plan for Alternative General Education records, Collection #R0014, Special Collections and Archives, George Mason University. Retrieved on March 10, 2012 from [http://sca.gmu.edu/finding\\_aids/gmupage.html](http://sca.gmu.edu/finding_aids/gmupage.html)
- George Mason University. (n.d.). *A brief history of George Mason University*. Retrieved March 10, 2012 from <http://www.gmu.edu/resources/visitors/history>.
- George Mason University Office of Institutional Assessment. (2010, Sept. 10). *Scientific Reasoning assessment results: A value-added analysis, September, 2008*. Scientific Reasoning page. Retrieved on March 10, 2012 from <https://assessment.gmu.edu/StudentLearningCompetencies/Scientific/index.html>.
- George Mason University Office of Institutional Assessment. (2010, September). Student learning competencies, Scientific reasoning page. Retrieved on March 10, 2012 from <https://assessment.gmu.edu/StudentLearningCompetencies/Scientific/index.html>.
- George Mason University Office of Institutional Assessment. (2011, October 4). General education assessment overview. Retrieved on March 10, 2012 from <https://assessment.gmu.edu/Genedassessment/index.html>.
- George Mason University Provost's office (2010). General education requirements page. Retrieved on January 26, 2012 from <http://provost.gmu.edu/gened/general-education-requirements/>.
- George Mason University Provost's office. (2011, March). *Life, liberty and the pursuit of happiness: A rationale for general education at George Mason University*. Fairfax, VA: George Mason University. Retrieved from <http://provost.gmu.edu/gened/>.
- Giere, R. (1997). *Understanding Scientific Reasoning*. 4<sup>th</sup> ed. New York: Holt, Rinehart & Winston.
- Gordon, M. (2009). Toward a pragmatic discourse of constructivism: Reflections on lessons from practice. *Educational Studies*, 45, 39-58. doi: 10.1080/00131940802546894
- Green, P.J. (2003). *Peer instruction in Astronomy*. Upper Saddle River, NJ: Pearson Education.

- Hammer, C. & Dusek, V. (2006). The rationale and challenge for the integration of science studies in the revision of general education curricula. *The Journal of General Education*. 55:1. DOI: 10.1353/jge.2006.0015.
- Hammer, D. (1996). Misconceptions or P-Prims: How may alternative perspectives of cognitive structure influence instructional perceptions and intentions? *The Journal of the Learning Sciences*, 5(2), 97-127, retrieved from <http://www.csun.edu/learningnet/TeachScience/UPimages/f/f8/Hammerminsconceptions.pdf>.
- Hart Research Associates. (2004). *Qualitative research for the association of American Colleges and Universities*. AAC&U. Retrieved from <http://www.aacu.org/leap/pdfs/HartFocusGroupResearchReport.pdf>
- Hart Research Associates. (2009). *Trends and emerging practices in general education*. AAC&U. Retrieved on July 4, 2009 from [http://www.aacu.org/membership/documents/2009MemberSurvey\\_Part2.pdf](http://www.aacu.org/membership/documents/2009MemberSurvey_Part2.pdf)
- Henderson, C., Finkelstein, N., and Beach A. (2010). Beyond dissemination in college science teaching: An introduction to four core change strategies. *Journal of College Science Teaching*, 39(5), 18-25.
- Herr, K. & Anderson, G.L. (2005). *The action research dissertation: A guide for students and faculty*. Thousand Oaks, CA: Sage Publications.
- Hersh, R.H. & Merrow, J. (2005). *Declining by degrees: Higher education at risk*. New York, NY: Palgrave MacMillan.
- hooks, b. (2010). *Teaching critical thinking: Practical wisdom*. Routledge: New York.
- Gamson, Z.F. and Associates. (1984). *Liberating education*. New York, NY: Jossey-Bass.
- Keen, R.C., Mitchell, N.D. & Wilson, D.E. (2008). Toward intentionality and transparency: Analysis and reflection on the process of general education reform. *Peer Review*. Fall 2008. 4-8.
- Keller, G.E.III (2002). Using problem-based and active learning in an interdisciplinary science course for non-science majors. *The Journal of General Education*, 51(4), 272-281.
- Kerr, C. (2001). Idea of a Multiversity. *Uses of the University*. Harvard University Press: Cambridge, Ma, 1-33.

- Kilpatrick, W.H. (1951). *Philosophy of education*. New York, NY: The Macmillan Company.
- Kirp, D.L. (2003). *Shakespeare, Einstein, and the bottom line: The marketing of higher education*. Cambridge, MA: Harvard University Press.
- Krug, E. (1961, September). Charles W. Eliot and the secondary school. *History of Education Quarterly*, 1(3), 4-21. doi: 10.2307/366923
- Kuh, G.D. (2008). *High-impact education practices: What they are, who has access to them, and why they matter*. Washington, DC: AAC&U.
- Laird, T.F, Shoup, R. Kuh, G.D., & Schwarz, M.J. (2008) The effects of discipline on deep approaches to student learning and college outcomes. *Research on Higher Education*, 49:469-494. DOI 10.1007/s11162-008-9088-5.
- Leskes, A. & Wright, B.D. (2005). *The art & science of assessing general education outcomes: A practical guide*. Washington, DC: AAC&U.
- Levine, D.N. (2006). *Powers of the Mind*. Chicago, IL: University of Chicago Press.
- Lising, L. & Elby, A. (2005). The impact of epistemology on learning: A case study from introductory physics. *American Journal of Physics*. 73(4), p. 372-382.
- Lodico, M.G., Spaulding, D.T. & Voegtler, K.H. (2010). *Methods in Educational Research: from theory to practice*. San Francisco, CA: Jossey-Bass.
- LoPresto, M. C., & Murrell, S. R. (2011). An Astronomical Misconceptions Survey. *Journal Of College Science Teaching*, 40(5), 14-22.
- Lucas , L. J. (2010, October). Awake, accountable, and engaged. *National Teaching and Learning Forum*, Vol. 19, No. 6 Retrieved from <http://cgi.stanford.edu/~dept-ctl/cgi-bin/tomprof/posting.php?ID=1060>
- Marinara, M., Vajravelu, K. & Young, D.L. (2004) Making sense of the “loose baggy monster”: Assessing learning in a general education program is a whale of a task. *The Journal of General Education*. 53(1).
- Marzano, R.J. Gaddy, B.B. & Dean, C. (2000, August). What works in classroom instruction? Mid-continent Research for Education and Learning (McREL):Denver,Co. retrieved from [http://www.mcrel.org/PDF/Instruction/5992TG\\_What\\_Works.pdf](http://www.mcrel.org/PDF/Instruction/5992TG_What_Works.pdf).

- Mauldin, R. & Lonney, L. (1999). Scientific reasoning for nonscience majors: Ronald N. Giere's approach. *Journal of College Science Teaching*. 28(6) 416.
- Mazur, E. (1997). *Peer instruction: A user's manual*. Upper Saddle River, NJ: Prentice Hall.
- McDermott, L.C., & the Physics Education Group at the University of Washington. (1996). *Physics by inquiry*. New York, NY: John Wiley & Sons.
- McDonald, J., & Dominguez, L. (2009). Developing Patterns for Learning in Science Through Reflection. *Journal Of College Science Teaching*, 39(1), 38-42.
- Mestre, J.M. (2012). Learning goals in undergraduate STEM education and evidence for achieving them. Board on Science education, National Academy of Sciences. Retrieved from [http://www7.nationalacademies.org/bose/Mestre\\_CommissionedPaper.pdf](http://www7.nationalacademies.org/bose/Mestre_CommissionedPaper.pdf)
- Nair, I. (2011). New scientific literacies for an interdependent world. *Diversity and Democracy: Civic learning for shared futures*. 14:2. Retrieved from <http://www.diversityweb.org/DiversityDemocracy/vol14no2/vol14no2.pdf>
- The National Commission on Excellence in Education. (1983, April). A nation at risk: The imperative for educational reform. US Department of Education. Retrieved on April 2, 2011 from <http://www2.ed.gov/pubs/NatAtRisk/index.html>.
- National Educational Association of the United States. (1894). The Report on the Committee of Ten on Secondary school studies. New York: The American Book Company. Retrieved from <http://ia700200.us.archive.org/6/items/reportofcomtens00natirich/reportofcomtens00natirich.pdf>
- National Research Council. (2002). *Scientific research in education*. Committee on Scientific Principles for Education Research. R. J. Havelson and L. Towne (Eds.). Washington, D.C.: National Academy Press.
- Nehm, R. & Reilly, L. (March 2007). Biology majors' knowledge and misconceptions of natural selection. 57(3), 263-272.
- Newton, R. R. (2000) Tensions and models in general education planning. *The Journal of General Education*. 49 (3).
- Novak, G., Gavrin, A., Christian, W. & Patterson, E. (1999). *Just-in-time teaching: Blending active learning with web technology*. Upper Saddle River, NJ: Prentice-Hall.



- NSF. (February 3, 2012). Division of Social and Economic Sciences. Science, technology and society page. Retrieved from [http://www.nsf.gov/funding/pgm\\_summ.jsp?pims\\_id=5324](http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5324)
- NSF (2006). Chapter 1: Elementary and secondary Education: Student course taking in math and science. *Science and engineering indicators 2006*. Retrieved from <http://www.nsf.gov/statistics/seind06/c1/c1s2.htm>
- Nunn, C.E. (1996, May/June). Discussion in the college classroom: Triangulating observational and survey results. *Journal of Higher Education*, 67( 3).
- Otero, V., Pollock, S., McCray, R. and Finkelstein, N. (2006). Who Is Responsible for Preparing Science Teachers? *Science*, 28 July 2006, 445-446. doi:10.1126/science.1129648
- Patton, M.Q. (2002). *Qualitative research & evaluation methods* (3<sup>rd</sup> ed.) Thousand Oaks, CA: Sage Publications.
- Pintrich, P.R. (2003). A Motivational Science Perspective on the Role of Student Motivation in Learning and Teaching Contexts, *Journal of Educational Psychology*, 95(4), 667–686. Retrieved from [https://netfiles.uiuc.edu/bwmiller/shared/epsy552/March29/Pintrich\\_Motivation.pdf](https://netfiles.uiuc.edu/bwmiller/shared/epsy552/March29/Pintrich_Motivation.pdf).
- Plummer J. & Howard, L. (2005). Teaching Science to Non-Majors presentation retrieved from [http://www.aacu.org/SharedFutures/tools/Non-Science\\_Majors.cfm#q1](http://www.aacu.org/SharedFutures/tools/Non-Science_Majors.cfm#q1) July 2, 2009.
- Project 2061. (1989). *Science for all Americans: A Project 2061 report on literacy goals in science, mathematics, and technology*. Washington DC: American Association for the Advancement of Science.
- Ratcliff, J.L. (2004, Spring). Re-envisioning the change process in general education. *New Directions for Higher Education*. 125, 97-118.
- Redish, E.F. (2003). *Teaching physics with the physics suite*. Hoboken, NJ: John Wiley & Sons.
- Reuben, J.A. (1996). *The making of the modern university: Intellectual transformation and the marginalization of morality*. Chicago, IL:University of Chicago Press.

- Rhodes, F.H.T. (2010). Science as a liberal art. In Meinwald, J. & Hildebrand, J.G. (Eds) *Science and the educated American: A core component of liberal education*. (pp. 23-40), Cambridge, MA: American Academy of Arts and Sciences.
- Robinson, V. (1993). *Problem-based methodology: Research for the improvement of practice*. Tarrytown, NY: Pergamon Press.
- Robson, D.W. (1983, autumn). College founding in the new republic, 1776-1800. *History of Education Quarterly*, 23(3), 323-341.
- Rosenberg, J.L., Lorenzo, M. & Mazur, E. (2006). Peer instruction: Making science engaging. In Joel J. Mintzes & William H. Leonard (Eds.) *Handbook of college science teaching* (pp.77-85). Arlington, VA: NSTA Press.
- Roseman, J.E. & Koppal, M. (2006). *Ensuring that college graduates are science literate: Implications of K-12 benchmarks and standards*. NSTA. Retrieved from <http://www.project2061.org/publications/2061Connections/2006/media/handbook.pdf>
- Roth, W-M. & Lee, S. (2002). Scientific literacy as collective praxis. *Public Understanding of Science* 2002 11(33). DOI:10.1088/0963-6625/11/1/302.
- Rudolph, F. (1990). *The American college & university: A history*. Athens, GA: University of Georgia Press.
- Rudolph, J.L. (2002). *Scientists in the classroom: The cold war reconstruction of American science education*. New York, NY: Palgrave.
- Rudolph, J.L. (2005, Fall). Epistemology for the masses: The origins of “The Scientific Method” in American schools. *History of Education Quarterly*, 45(3). 341-376.
- Rudolph, J.L. (2005, September). Turning science to account: Chicago and the general science movement in secondary education. 1905-1920. *Isis*. 96 (3), 353-389.
- Rutherford, F.J. (2005, December). The 2005 Paul F-Brandwein lecture: Is our past our future? Thoughts on the next 50 years of science education reform in the light of judgments on the past 50 years. *Journal of Science Education and Technology* 14(4). Doi:10.1007/s10956-005-8082-3.
- Schwartz, T. (2007, January 26). Macalester College. Interview with Truman Schwartz, Professor of Chemistry. Digital Commons @ Macalester. Chemistry Department Oral Histories retrieved from [http://digitalcommons.macalester.edu/chem\\_oralhist/1/](http://digitalcommons.macalester.edu/chem_oralhist/1/).

- Seaborg, G.T. (1966, October). Goals in understanding science. Excerpts from Seaborg's speech at Arches of Science award banquet, Oct. 19, Pacific Science Center, Seattle, WA. *Science News*. 90(20), 354-356.
- SENCER (2012). *Science education for new civic engagements and responsibilities*. SENCER ideals page. Retrieved from <http://www.sencer.net/About/sencerideals.cfm>
- Seymour, E. & Hewitt, N.M. (1997). *Talking about leaving: Why undergraduates leave the sciences*. Boulder, CO:Westview Press.
- Shavelson, R.J. & Towne, L. (Eds.). (2002). *Scientific Research in Education*. Washington, DC. National Academy Press.
- Shoenberg, R. (2005). *General education and student transfer: Fostering intentionality and coherence in state systems*. AAC&U:Washington DC.
- Shoenberg, R. (2000). "Why do I have to take this course?" or Credit hours, transfer and curricular coherence. *Peer Review*. Retrieved from <http://www.aacu.org/peerreview/pr-wi00/pr-shoenberg.cfm>.
- Singer, S. (2008) *Linking evidence and learning goals*. Board on Science Education of The National Academies. Retrieved from NRC website at [http://www7.nationalacademies.org/bose/PP\\_Commissioned\\_Papers.html](http://www7.nationalacademies.org/bose/PP_Commissioned_Papers.html)
- Slater, T. & Adams, J.P. (2003). *Learner-centered astronomy teaching: Strategies for Astro 101*. Upper Saddle River, NJ: Pearson Education.
- Smith, M. (1949). *And madly teach*. p. 13. Chicago, IL: Henry Regnery Company. Retrieved from The Humanist Library at <http://www.archive.org/details/andmadlyteachthe007630mbp>.
- Smith, M.K., Wood, W.B., Adams, W.K., Wieman, C., Knight, J.K., Guild, N. & Su, T.T. (2009). Why Peer Discussion Improves Student Performance on In-Class Concept Questions. *Science*, 323, 122-124, doi:10.1126/science.1165919
- Smith, V.R., Brunton, B. G., & Kohen, A. I. with Gilliatt, C.A., Klippert, J. C., & Marshall, C.T. (2001). General education reform: Thinking critically about substance and process. *The Journal of General Education*. 50 (2).
- Snow, C.P. (1969). *The two cultures*. New York, NY: Cambridge University Press.

- Stage, F.K. & Kinzie, J. (2009). Reform in undergraduate science, technology, engineering, and mathematics: The classroom context. *The Journal of General Education*, 58:2, pp. 85-105. DOI 10.1353/jge.0.0038.
- Swan, M. (2011). Towards the creative teaching of mathematics: a design research approach. In P. Thomson, & J. Sefton-Green (Eds.), *Researching creative learning: Methods and issues* (pp. 54-69). New York, NY: Routledge.
- Trefil, J. (2008). *Why Science?* Arlington, VA:NSTA.
- Trefil, J. & Hazen, R.M. (2010). Scientific literacy: A modest proposal. In Meinwald, J. & Hildebrand, J.G. (Eds.) *Science and the educated American: A core component of liberal education* (pp. 57-69)Cambridge, MA: American Academy of Arts and Sciences.
- The University of California Commission on General Education. (2007). *General education in the 21<sup>st</sup> century: A report of the University of California Commission on General Education*. Center for studies in Higher Education: UC Berkeley. Retrieved from <http://escholarship.org/ux/item/1245x2bn>.
- University of Maryland Physics Education Group. (1997). *Student Expectations in University Physics: MPEX*. Retrieved July 24, 2009 from <http://www.physics.umd.edu/perg/expect/mpex.htm>.
- Voparil, C.J. (2008). A new name for some old ways of teaching: Dewey, learning differences, and liberal education. *Education and Culture*, 24(1) 34-49.
- Wheelock, F.M & LaFleur, R.A. (2005). Forward, *Wheelock's Latin, 6<sup>th</sup> Edition Revised*. p. ix. New York:HarperCollins.
- Wright, M. (2005, May/June). Always at odds? Congruence in faculty beliefs about teaching at a research university. *The Journal of Higher Education*. 76(3).
- Yale College. (1828) *Reports on the course of instruction in Yale College*. Retrieved from <http://collegiateway.org/reading/yale-report-1828/>
- Zimba, Jason. (2009). Five areas of core science knowledge: What do we mean by “STEM-capable”? *The Opportunity Equation, The Carnegie Corporation of New York, Institute for Advanced Study*. Retrieved on July 2, 2009 from <http://www.opportunityequation.org/resources/commissioned-papers/zimba/>

## **CURRICULUM VITAE**

Rebecca Ericson graduated from McCall-Donnelley High School in McCall, Idaho in 1966. She received her Bachelor of Arts from Macalester College in 1970 and her Master of Science from Creighton University in 1973. She raised four sons and was employed as an adjunct science instructor in the Philippines, Australia, California, and Virginia during her husband's active duty military career. She worked for Northern Virginia Community College during the 1990s instructing developmental math, physics, natural science and astronomy before going to George Mason University as a term instructor in the Physics and Astronomy Department in 2005.