Common Ground for Three Cultures: Concordance Among Students, Non-Science Faculty, and Science Faculty on Perceptions of Science Course Goals

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Abstract

Science has been considered a distinct culture within academics. Do faculty and students from outside of the sciences agree with the relative importance of goals for science courses designed by scientists? We surveyed science faculty, non-science faculty and students enrolled in non-majors science courses and found little evidence for a cultural divide between non-scientists and scientists.
Introduction

More than 50 years ago, C.P. Snow described the divide between scientists and non-scientists in his now-famous Rede Lecture, “The Two Cultures and the Scientific Revolution” (Snow, 1959). Although Snow has been criticized for making broad generalizations based on a relatively narrow frame of reference (Gould, 2003), the idea that there is a gap in both worldview, and the ability to communicate those views, persists among both scientists and non-scientists (Koshland, 1985; Herrnstein, 2005; Trefil, 2008). For example, science educators in the United States continue to lament a general lack of scientific literacy among the general public (e.g., Goodstein, 1992; Greenwood & Kovacs, 1999; Miller, 2004) and have called for educational reform in both K-12 (Rutherford & Ahlgren, 1989; deBoer, 2000; Turner, 2008; Pearson, Moje & Greenleaf, 2010) and college (Nelson, 1999; Cook & Mulvihill, 2008) curricula.

Recognition that science is an important part of a liberal arts education is reflected in the fact that most college general education curricula require students to take at least one science course and, in general, these courses are specifically designed for non-science majors.

Science courses for non-science majors differ from those for science majors in both the attitudes and expectations that students bring to the course as well as the goals of faculty for students completing the course. Compared to science majors, students majoring in disciplines outside of science tend to have a more negative attitude about science (Gogolin & Swartz, 1992), less confidence in their ability to be successful in a science course (Duchovic, Maloney, Majumdar & Manalis, 1998; Baldwin, Ebert-May & Burns, 1999), and, in some cases, greater conflicts between scientific perspectives and their personal beliefs. Because the good intentions of a broad general education curriculum can elude undergraduates, faculty designing non-majors courses must consider an audience that consists of students who are in the course simply to fulfill a requirement and not necessarily because of a compelling interest in the subject matter or discipline (Smith, Gould & Jones, 2004; Glynn, Taasoobshirazi & Brickman, 2007; Cook & Mulvihill, 2008). Furthermore, the potential for a cultural divide between scientists and non-scientists brings into question the ability of scientists to bridge that gap in designing and implementing a course for non-scientists that meets the goals of both groups.

In this study, we recognized three constituencies that have a stake in the efficacy of our college science curriculum and also have the potential to represent three distinct “cultures”: science faculty, non-
science faculty, and students taking science courses for non-majors. While the general education curriculum at any university is expected to bridge the three cultures, the extent to which any one group (e.g., scientists) can create courses that meet the goals and expectations of the other two is less clear. Here we present the results of a series of surveys we conducted as part of a leadership initiative directed by Project Kaleidoscope (PKAL) with funding from the National Science Foundation that focused on our non-majors science curriculum. These surveys were designed to determine: a) the extent to which science faculty teaching non-majors courses embrace a series of previously adopted goals for those courses, b) the concordance between the importance science faculty and non-science faculty and students place on the stated goals for non-majors science courses, and c) the extent to which both science faculty and students in their non-science courses perceive the goals to have been met.

**Methods**

**The Participants.** The participants in our study were 11 science faculty members (seven in Biology, two in Chemistry and two in Physics) who teach non-majors science courses, 41 faculty from outside the sciences (out of approximately 60 who received the survey), and 117 students enrolled in three non-majors science courses (Human Nutrition, Environmental Biology or Chemistry in Everyday Life). Each science faculty filled out one survey for each non-major course they taught. Two instructors taught two courses while the other nine taught a single course, so there were a total of 13 surveys completed. Because some courses were taught by different instructors in different semesters, there were a total of 10 different course titles included. At the time the surveys were conducted, all students at the university were required to take a science course and all of the courses offered had a laboratory component that met separately from the lecture. The research adhered to university IRB practice. In particular, the survey was exempt from the university's IRB review processes given that the survey met the criteria for exemption (i.e., research participation was voluntary and anonymous, and the survey didn't request sensitive information, use active deception, or subject participants to mental or physical stress).

**The Survey.** As a foundation for our investigation, we used a set of goals for non-majors science courses that had been developed and unanimously approved by our faculty in the Division of Natural Sciences in 2001 (Table 1). The survey sent to science faculty during the 2005-06 academic year consisted of five Yes/No questions that related to an instructor’s knowledge of the goals and the degree to which they
explicitly introduced those goals to students (Table 2). A list of the 12 goals for non-majors courses and the instruction for respondents to state the degree to which each item was covered (hereafter referred to as coverage) using a Likert-type scale (strongly covered = 3, covered = 2, slightly covered = 1, not covered = 0, and not sure = NS) made up the second part of the survey. Following this was the same list and scale with the instruction to state the degree to which the participant believed each goal is an important component (hereafter referred to as importance) of the course taught. Student surveys were similar except that there were three, rather than five, Yes/No questions related to student knowledge of goals. Non-science faculty were given surveys with the same three Yes/No questions as the students and were asked only about perceived importance (and not coverage) for each of the twelve goals. None of the surveys asked respondents to suggest different goals.

For the surveys completed by students and science faculty, we calculated the average importance and coverage scores for each of the 12 goals. For the surveys completed by non-science faculty we calculated the average importance score for each goal. Using these averages, we calculated correlation coefficients to determine the strength of the relationship between: a) science faculty importance and coverage scores, b) science faculty and non-science faculty importance scores, c) science faculty and student importance scores, and d) science faculty and student coverage scores.
Table 1. A list of goals for non-majors courses developed and adopted by science faculty. This list of goals was distributed with surveys to both non-science faculty and students enrolled in non-majors science courses.

<table>
<thead>
<tr>
<th>Goal</th>
<th>Every non-majors science course should:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Teach a great deal about the methods of inquiry in the Natural Sciences. A diversity of methods (i.e. careful observation, experimentation, and modeling) should be addressed and students should understand the critical role of quantification and falsification in science.</td>
</tr>
<tr>
<td>2</td>
<td>Contain at least one highly detailed example of the immense utility of analytical mathematics in the description of natural processes.</td>
</tr>
<tr>
<td>3</td>
<td>Clearly distinguish between valid scientific methods and pseudoscientific studies.</td>
</tr>
<tr>
<td>4</td>
<td>Provide a clear example of how scientific knowledge progresses. This necessarily involves a historical component and should reveal how science has been advanced by new data, new ideas, and new interpretations. It should also show how advancement has sometimes been slowed by an unwillingness to deal with changing paradigms.</td>
</tr>
<tr>
<td>5</td>
<td>Develop the students’ abilities to speak clearly and persuasively about scientific methods and results.</td>
</tr>
<tr>
<td>6</td>
<td>Involve a large amount of active learning. All students should engage in a variety of learning experiences. The “laboratory” aspect of the course is critical to learning about both the concrete and abstract portions of a discipline.</td>
</tr>
<tr>
<td>7</td>
<td>Develop a curiosity and interest in the natural sciences in students that endures well beyond the end of the semester. <strong>To accomplish these goals, every non-majors science course should contain as many as possible of the following:</strong></td>
</tr>
<tr>
<td>8</td>
<td>A detailed example of the immense utility of computer simulations in understanding natural processes.</td>
</tr>
<tr>
<td>9</td>
<td>Examples of consilience (the strong unity of knowledge among the different disciplines of the natural sciences) in the natural sciences. Specifically, the instructor should show how knowledge originally developed in a different discipline ultimately had strong influences on the field of study.</td>
</tr>
<tr>
<td>10</td>
<td>Information that helps students develop an active appreciation of both the potential benefits and potential dangers of scientific advances.</td>
</tr>
<tr>
<td>11</td>
<td>Examples of how scientific knowledge helps inform responsible ethical decision making. When possible, the course should empower students with the scientific knowledge needed to conserve our environment.</td>
</tr>
<tr>
<td>12</td>
<td>Discussion of the aesthetic dimension of science--of what it means to seek an elegant theory and experiment. The students should develop a sense of the beauty of natural forces they explore and understand the need for commensurate beauty in scientific theory.</td>
</tr>
</tbody>
</table>
Results

Of the 11 instructors who completed surveys, more than half were aware of the goals at the time they taught the course, but a smaller percentage actually considered the goals when designing their course and none of them shared the goals with their students (Table 2). However, when asked about the goals after the course, instructors generally considered each of the 12 goals important. Given that there was significant overlap between science faculty who voted to adopt the 12 goals for non-majors science courses and those teaching the courses, there was limited variability in importance scores among the 12 goals. Mean importance scores ranged from 1.83 to 2.83. The goals with the highest importance scores were 1, 6, and 7 while goals 8, 9, and 12 (see Table 1 for description of goals) were considered least important. Similarly, goals 6 and 7 were those that instructors self-reported as giving the greatest coverage and goals 9 and 12 were given the least. Although there was strong agreement between importance and coverage scores reported by science faculty, Goals 3 and 6 were noticeable outliers in the relationship (Fig. 1), with Goal 3 being given less coverage than would be expected based on its importance score and Goal 6 being given greater coverage than expected. In general, importance scores ($\bar{x}_{\text{importance}} = 2.38, \text{sd} = 0.32$) were higher than coverage scores ($\bar{x}_{\text{coverage}} = 2.01$; $t = 2.96, p< 0.01$)

<table>
<thead>
<tr>
<th>Question</th>
<th># Yes</th>
<th>%Yes</th>
<th># No</th>
<th>%No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Did you know that we had a set of goals for non-majors courses?</td>
<td>8</td>
<td>61.5</td>
<td>5</td>
<td>38.5</td>
</tr>
<tr>
<td>2. Did you know what was stated in this set of goals?</td>
<td>8</td>
<td>61.5</td>
<td>5</td>
<td>38.5</td>
</tr>
<tr>
<td>3. Did you consider this set of goals when considering material for your course?</td>
<td>5</td>
<td>38.5</td>
<td>8</td>
<td>61.5</td>
</tr>
<tr>
<td>4. Did you share this list of goals with students?</td>
<td>0</td>
<td>0</td>
<td>13</td>
<td>100</td>
</tr>
<tr>
<td>5. Is this list of goals on your syllabus?</td>
<td>0</td>
<td>0</td>
<td>13</td>
<td>100</td>
</tr>
</tbody>
</table>
Faculty outside of the natural sciences tended to agree with scientists about the relative importance of the 12 goals (Figure 2). Student perceptions of importance, however, were more variable than those of either faculty group (Figure 3), although the positive linear relationship was still strong ($r = 0.55$). In particular, students tended to rate Goals 10, 11 and 12 as more important than would be expected based on the overall linear relationship between the two variables while faculty rated Goal 2 as more important than students.
Figure 2. Relationship between the importance science faculty and non-science faculty attribute to each of the 12 goals for non-majors science courses. Data points for the correlation are the average scientist and nonscientist importance scores for each goal and are symbolized on the graph by the number assigned to each goal in Table 1.

Figure 3. Relationship between the importance science faculty and students attribute to each of the 12 goals for non-majors science courses. Data points for the correlation are the average scientist and student importance scores for each goal and are symbolized on the graph by the number assigned to each goal in Table 1.
Discussion

Overall, there was a strong positive relationship between the importance science faculty placed on a goal and the self-reported coverage allotted in their courses. However, the majority of faculty stated that they did not consider the existing set of goals when designing their courses, and no faculty communicated the list of goals to their students, suggesting that instructors were not teaching toward the established goals. Thus, the strong correlation between self-reported coverage and importance may include the bias of responders who, in retrospect, assume they must have given heavy coverage to those items they felt were most important. On the other hand, almost all of the faculty we surveyed had reviewed and accepted the list of goals four years before the survey was administered, and the list was derived from discussions among the same faculty members about what/how they teach non-majors. Thus, the unspoken, individual goals of instructors were presumably similar to those adopted by the group, and could also account for the correspondence between reported importance and coverage.

One notable exception to the general pattern of a positive relationship between importance and coverage was that faculty placed a relatively high importance on distinguishing between science and pseudoscience ($\bar{x} = 2.46$), but reported relatively low coverage ($\bar{x} = 1.77$). The high importance attached to this goal is appropriate given the proliferation of pseudoscience in the mainstream media. The relative lack of coverage may reflect that pseudoscientific claims are more important and topical in some disciplines (i.e. the study of biological origins) than in other disciplines (i.e. physics of music). This lack of coverage could also reflect a reluctance of instructors to teach in areas outside their training (which typically doesn’t involve investigation of pseudoscientific claims) or a reluctance of instructors to delve into controversial subjects. Teaching science content does not necessarily increase student understanding of the nature of scientific inquiry (Johnson & Pigliucci, 2004). Thus, instructors of non-majors science courses should strike a balance between the presentation of content and examples of scientific process in order to increase critical thinking skills and the ability to distinguish between research-based evidence and unscientific claims.

Science faculty and students enrolled in non-majors science courses generally viewed the importance of the 12 goals similarly. Since students were surveyed at the end of the semester, their
perceptions of importance may have been, at least in part, shaped by the bias of their instructor. There were, however, several goals that were rated differently in terms of importance by faculty and students. In particular, students did not consider the utility of analytical mathematics in science (Goal 2) to be as important as faculty did. Math anxiety in college students is common (e.g., Perry, 2004), so this result was not completely surprising, but did cause us to reflect on our own views about the importance of math to science. Although quantitative techniques form the basis of scientific inquiry, a great deal of science can be understood without a firm grasp of the underlying mathematics (Trefil, 2008) and the inclusion of math in science courses could actually exacerbate the anxiety of non-science majors about both science and math.

We remain convinced that Goal 2 is important for non-majors for three main reasons:

1) solutions to some of the most important scientific issues facing civilization today (e.g., climate change, disease spread, water and food shortages) are being investigated using mathematical models, and a scientifically literate society needs to be able to understand the utility of such models even if the particulars of the model are unknown, 2) providing practical applications for mathematical models within a science course may actually reduce anxiety about math (Arnett & van Horn, 2009), and 3) if we want non-majors to understand the nature of scientific inquiry as well as absorb science facts, we cannot eliminate the mathematical component (Hohman, Adams, Heinrichs & Hickman, 2006). In fact, emphasizing the quantitative nature of science is one way to demonstrate the way in which questions are answered differently in science compared to non-scientific disciplines.

Given differences in the kinds of academic questions that are asked by non-scientists and scientists, a cultural divide between the two groups would be expected to be manifested in the relative importance of educational goals in the disciplines. Our surveys, however, suggest that the divide may be smaller than anticipated. In general, the relative importance of the course goals rated by scientists is similar to that of non-scientists. Perhaps most striking is the fact that this agreement was similar even for those goals related to the application of science to societal concerns (i.e., Goals 10, 11, and 12). Our results may be biased by the fact that non-science faculty who responded may have been those predisposed to thinking positively about science and scientists, although faculty respondents came from
our School of Business (n=8), School of Music (n=6), and College of Arts and Sciences (n=27). Furthermore, faculty in all disciplines likely share an academic interest in "ways of knowing" that results in a correspondence between scientists and non-scientists for the importance of learning goals. This commonality, combined with the act of scientists reaching out to non-science faculty by asking their views about our courses, may have also had some non-tangible rewards in bridging the cultural divide.

The fact that we created a list of goals for non-majors courses reflects that, at our institution, we teach non-science majors differently from science majors, and perhaps suggests that we are guilty of deepening the cultural divide. We argue, as have others (e.g., Wright, 2005), that non-majors courses are less bound by content than those for majors and should be designed to create citizens who appreciate and understand science, not to create scientists (Trefil, 2008; but see Sundberg & Dini, 1993; Klymkowsky, 2005). Thus, while our goals may not necessarily translate to curricula for non-science majors at other institutions, their approval at our university by all math, chemistry, biology, and physics faculty members satisfies us that they are consistent with the purpose of including a natural science course within our general education curriculum. Furthermore, while our surveys did not allow respondents to suggest additional goals, the general agreement of importance between scientists and non-scientists suggests that others at our institution agree with our approach.

In conclusion, there were two positive outcomes from simply distributing our surveys to faculty. By reminding science faculty about the previously agreed upon goals of our non-majors courses, we encouraged them to think broadly about course content and management and to consider the relationship between what they consider to be important and the material they actually include in their courses. After we distributed our surveys, several faculty teaching non-science majors modified their course content and included the 12 goals on their course syllabi, something that none had done previously. We do not know whether this explicit inclusion on the syllabus increased efforts to teach toward the goals, but our findings provide a starting point for a discussion about course design (e.g., Wiggins & McTighe, 2005; Handelsman, Miller & Pfund, 2006). The distribution of the survey and goals to non-science faculty also demonstrated that science faculty recognize that classes designed for non-science majors should have different foci than courses for science majors who will take many science courses in multiple disciplines during their academic career. By giving our non-science colleagues a voice in the development of these
courses, we acknowledged that an understanding of the differences between these groups is needed to
effectively teach students from across Snow's cultural divide. Finally, the results of our study showed that
the cultural divides between different faculty groups and students are narrower than we expected, which
bodes well for maintaining a central place for science in a liberal arts education. While our research
sample was limited to faculty and students at one small institution, it would be interesting to know whether
a narrower-than-expected cultural divide also exists at larger and/or international universities.

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