WHERE DO IDEAS IN SCIENCE COME FROM?:

TEACHING LIGHT AND VISION AS

A CASE STUDY

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The belief that the "scientific method" provides a degree of certitude not available in the humanities or social sciences helps to attract many students to careers in engineering. An important goal, then, of an interdisciplinary program at an engineering college is to subject a simplistic notion of the "scientific method" to appropriate scrutiny. The course "Light and Vision" described here attempts to open science, engineering and management studies at WPI to the ideas of writers like Thomas Kuhn and Gerald Holton concerning how ideas and innovations in science arise.

How "Light and Vision" was formulated is perhaps best understood by considering its development in the context of WPI's recent revaluation of its program and goals. In reorganizing its curriculum in the late 1960's, WPI placed a much greater emphasis on interdisciplinary studies than is common at engineering-oriented colleges. In place of conventional course and distribution requirements for determining the major, the WPI faculty defined four new competence-based degree requirements as the qualifications for an engineering or science major. Two of these requirements--an examination and a project--are in the major, while the other two, a humanities minor and an interactive project, develop the student's strengths in liberal studies.

The interactive project is perhaps the most innovative part of WPI's program. Students are asked to define, research and write up some topic of their choice linking science and technology to a social need or issue. The method of study in this interdisciplinary project depends on the problem chosen as well as student interest and background. Many but not all students select problem-solving topics in areas like environmental studies or consumer protection where the social impact of technology is defined by economic or legal methodologies.

Given the pragmatic and operational cast of engineering education, it is understandable that many of our students are attracted to interactive projects using a modeling or case-study approach to examine the impact of technology on society. To provide an alternative to this kind of project, a faculty group sought the formulation of projects of a more theoretical and conceptual nature. We wished to stimulate students to devise topics which related science and technology to society via a bridge in the humanities or arts. Thus in 1971-72, a group of faculty drawn from chemistry, physics, mechanical engineering, life sciences, art, history of science and literature began meeting to share ideas for interdisciplinary projects which could help students place science and technology in larger historical, phiiosophical or cultural contexts.

The following academic year, the group began working with some juniors on a series of projects to explore the development of Western science within this larger frame. The goal of these projects was to challenge our engineering, science and management majors to raise one or more of the three following questions:

1. Where do scientific ideas come from?

2. How is the "correctness" of scientific ideas determined?

3. Does creativity in science and in the arts differ in its basic nature?

Not surprisingly, we encountered from the students for all three questions an initial naive response, born of their earlier conceptualization of these questions and reinforced by the problem-solving orientation of subsequent studies. These responses may be summarized as follows:

1. Ideas in science emerge from the application of the "scientific method" of experiment leading to deducing the underlying principles from the resultant data. In this process of deduction, the subjective or intuitive role of the scientist is submerged; scientific laws in fact claim their potency from being freed from mere personal or individual bias.

2. Ideas in science are proven correct by matching the results of their application to the objective world. Different workers, separated by time and space, finding a correspondence between Nature and a law proposed for verification, thereby affirm the correctness of the proposed law. Again, the test is comparison with an objective nature, within which rests, awaiting discovery, the patterns of order which the scientist discloses.

3. Thus, the process of creating something new is fundamentally different in the arts and the sciences. Scientists draw from data amassed from objective reality, whereas artists or humanists depend upon subjective intuitions or emotional expressions. Snow is correct in suggesting that the gap between the "Two Cultures" has become fundamental and unbridgeable.

With challenging these views in mind, the faculty group began working with some sophomores and juniors to flesh out some appropriate projects. One or more faculty advised one or more students on individual topics, with the whole group assembling once a week to investigate common ground. The experience which resulted will not surprise anyone who has attempted a similar enterprise: the difference in approach and opinion of the eight faculty dominated discussion, with students--whose experience in such free-wheeling confabs was limited--shrinking into physical and intellectual corners. After the first year of project work, it became apparent that students needed an exposure to the methods of interdisciplinary studies at a level more basic than what was expected of them in doing original project work.

In the summer of 1973, with support from a General Electric Foundation grant, the faculty group set out to design a course which would develop a model for interdisciplinary research, as well as present a rich enough diversity of topics to appeal to a wide constituency of student interests. The topic chosen was "Light and Vision," for several reasons. As we now conceptualize the process of seeing, both an objective stimulus--light--and a subjective response--seeing--is involved. The clarification of seeing as a psychological interpretation of objective data is of recent origin, and the centuries of thinking about seeing which preceded this distinction are rich in exampies of how hypotheses emerge from underlying assumptions, or what Gerald Holton calls "themes." The phenomenon of vision is so embedded in our unquestioned daily routine, that it constitutes a test case for how scientific abstraction treats so commonplace yet so vital a part of our accepted environment. The question of how many people have responded to light and vision is woven through practically every present-day "discipline"--through not only virtually all the physical and psychological sciences, but through art, literary imagery, and religious and mythological constructs. Correspondences abound which illustrate how in different eras scientific and artistic innovations concerning light and seeing influence one another. Finally, consideration of how little we really know today about either light or vision--whether light is particle or wave, how the brain formulates a rich colored and dimensioned "picture" of the world from nerve impulses--reminds us and our students of our limits, and sets any sense of inevitable "progress" from ignorance to knowledge in a proper frame.

"Light and Vision" was first offered in the spring quarter of 1974. The initial presentation again erred by offering too much material, thus overwhelming the students and submerging the important themes. After several years¹ experience, a more compact set of topics emerged, which centered around four modules:

1. The earliest mythic accounts of light, which (in Holton's terms} offered "multiform, undifferentiated, anthropomorphic" accounts of the central role light played in creation stories, leading to a separating out of different disciplines

among the Greeks and the emergence of the first "scientific" ideas about light and seeing.

2. The transition from medieval to Renaissance ideas about seeing, which is mediated by the development of linear perspective in art; where changes in art take the lead in offering a fresh view of what "seeing" is.

3. Newton's formulation of the essentially modern idea of the relationship between light and seeing in The Opticks, which not only offered a theory of light which was articulated into Newton's worldview dominated by God and gravity, but which also presented a bold formulation of a scientific method ostensibly based upon experiment and deduction. The impact of Opticks is examined in terms of both scientific and non-scientific responses.

4. The revolution in physics associated with relativity and quantum mechanics, and the relationship of this shift in worldview to the development of non-representational art.

To tie these modules together, the lecturers try to demonstrate a constant "deallegorization" (again, Holton's term) whereby the disciplinary strands implicit in the earliest creation myths increasingly take on separate methodologies; the initial "multiform" myth where religious, scientific and artistic responses to light rubbed shoulders breaks down into increasingly specialized and distinctively modern disciplines. Historically, texts range from excerpts from an Akkadian creation myth to elementary descriptions of quantum mechanics; in terms of disciplines, developments in physics, physiology and psychology are presented along with extensive discussions of the origin of Renaissance linear perspective, of Impressionism, and of Cubist art.

By means of the lectures, class discussions, and assignments, students encounter a version of the "scientific method" which, we hope, is more sophisticated and realistic than the naive view sketched initially above. Specifically, we stress Holton's idea of the importance of "themes" (personal assumptions or presuppositions which the scientist absorbs, often unawares, from the surrounding tradition and culture). Thus, a theme in science serves to filter out from the myriad of possible collectible data and structuring models just that evidence and model which fit the scientist's style--and may just lead to a scientific revolution. Examples touched upon in the class are Newton's assumption that light is a particle (and thus like the rest of his universe responsive to gravitation) and Einstein's confidence that "God does not play dice" with Nature's laws

With the framework of Holton's essays on scientific creativity, a more complex model may be developed of how the "correctness" of scientific ideas is decided. Using also Kuhn's well-known idea of the paradigm, we introduce students to the roie in accepting or rejecting new ideas which the community of scientists plays. The naive sense of nature as an ultimate objective reality against which all scientific ideas are tested is further challenged by the interpretations of quantum physics of Heisenberg and Bohr (contra Einstein); here the observer acquires a significant influence in deciding the results of an experiment. Simply put, in the pursuit of scientific truth, the questions researchers ask become as important as the answers nature yields.

Those students who grasp the points Holton and Kuhn are making about scientific creativity (and it would be unreasonable to expect that all do), are prepared to reconsider Snow's notion of the gap between science and the humanities as uncrossable. Both scientists and artists use both reason and intuition, objective observations and subjective feeling. Newton's finding seven colors in the spectrum, Einstein's hostility to a probabilistic interpretation of quantum mechanics, do not arise from the phenomena; such intuitive choices reflect personal styles as fully subjective as the idiosyncracies of an artist's style. Artists reason, scientists feel their way towards their results, just as much as the other way around.

Clearly what I have outlined above are the faculty's goals for the course--not every student emerges with a secure sense of each point. But evaluations indicate that most students do grasp the underlying arbitrariness of a simplistic and reductive model of scientific research. Interest in the course has remained gratifyingly stable since its inception in 1974, with between eight and twenty-four students enrolled in the annual offering; the most recent class had eighteen. Students can use the course in the humanities minor as well as a basis for further interdisciplinary work. The course is taken as part of a humanities program most commonly by students minoring in history of science or of art, or in philosophy. (The WPI minor consists of five thematically-related courses capped by an independent study.)

Interdisciplinary courses are often born in great excitement but too often languish and die as the faculty staffing them lose interest or support. "Light and Vision" fortunately has a secure if not enormous base of student interest as a component in the required humanities minor. The externally-funded group of eight who designed and first gave the course has undergone some shrinkage because of changes in professional interest. At present, two of us, professors of literature (the present author) and of chemistry, coordinate the course, presenting most of the lectures and leading all the conferences (there's a double session each week for discussion of issues raised in reading the Holton essays.) Each of us is present at every session, though direct interactions are usually limited to the conferences. We make an attempt to cover material in the lectures with which we normally are not associated professionally; I do most of the lectures on Newton, one on modern physics, and two on thematic debates in psychology of perception. My colleague in chemistry does all the lectures in art, along with the remainder of the topics in modern science. Thus we try to present ourselves as role-models for interdisciplinary studies, as well as lecturers.

In summary, then, "Light and Vision" serves the purpose of introducing students to interdisciplinary studies by raising questions about how creativity in science is influenced by the traditions and conventions of the culture in which the creative scientist is embedded. The course seeks also to present an extended case-study of ideas about how we see and what light is, drawing for evidence upon as wide a range of topics as we can. The course has found a secure niche in our curriculum as a component students may use in self-designed humanities minors, as well as in preparing some students for continued independent research in interdisciplinary studies which may satisfy WPI's second non-technical degree requirements. The two faculty most closely associated with the course have enjoyed the opportunity to work with students in topics outside their usual area of expertise, and have in both cases become engaged in new areas of professional research arising from topics first broached in preparing for the course.

Best of all, some of our students have come to recognize that science is not the coldly objective, mechanistic process of guaranteeing successful results by applying an infallible "method." Science is not the antithesis or antagonist of the Arts. Scientists, like artists, make use of intuitions, of assumptions which do not arise from the data they address. In ways which differ in degree but perhaps not in kind, both scientists and artists observe the fine structure of the external world. The patterns they "see," they half observe, half create.