

## THE SCIENCES AND THE HUMANITIES

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SOME CONSIDERATION of the relationship of the sciences to the humanities should have a place in the education of an engineer. It is a perennial issue and underlies many others that come to the surface in different forms at different times and flourish for a season. The question of the social responsibility of the engineer, for example, which has rightly attracted a lot of attention in the last few years, is rooted in the whole question of morality of knowledge, scientific or humanistic, and hence of their relationship to one another. "The Sciences and the Humanities" can indeed be the title for and the subject of a complete course, but it is also suitable for a more discursive seminar, perhaps promoted informally within a department, where it can be a valuable and healthy ventilation of ideas. However, since little but turbulence may result from throwing all the windows open at once and even the most informal of styles requires some underlying structure, the following outline of ideas is adumbrated in the hope that it may be serviceable. It does not attempt to lay out a topic by topic syllabus, for this, as we shall show, would be inappropriate,

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but it does try to examine some of the considerations which the first author's experience in teaching such a course over the last 14 years has shown to be cardinal and which the second author's attempt to grasp has proved to be slippery.

An inescapable feature of the course which we propose is that it does not have the type of content that many have come to expect from courses in the established subject areas. This does not mean that it is devoid of "content" but rather that it does not have the customary, or "normal" content. It does not enhance the kind of educational talent which impresses the general public. Students do not emerge from it as better engineers or researchers nor do they acquire a deeper appreciation of political or legal process, or find their esthetic sensibilities elevated. The absence of normal content may at first be disturbing for the course does not, to put it bluntly, seem to be *about* anything. It does not impart information about the gene or atom or instruct the student in the subtleties of literary expression or sharpen his ability to manage the practical problems of life. A course in the Sciences and the Humanities is not "science," nor is it "humanities." But neither should it be another adventure in random curricular hybridization or an interdisciplinary pastiche of materials drawn from the two sectors in the hope of attaining a grand and ultimate fusion of knowledge. What, then, is it?

It is perhaps helpful to distinguish between two general kinds of course content. The one, with which we are the most familiar, possesses what might be called "first-order" content. In such a course the emphasis is on the orderly transfer of information. This may be empirical information concerning natural processes or social systems or theoretical information such as the structure of a mathematical theory. There are other courses whose content is of the first order even though their content cannot so readily

be formulated as a series of testable propositions. For example, a course which focuses systematically upon certain themes, such as the rise of positivism in the nineteenth century, or on certain questions such as the comparative development of Greek and Babylonian astrology. These do not engage the student at the level of cumulative empirical information but require that he grasp complex, and often highly abstract, issues and ideas. It is characteristic of courses with first-order content that they are about something. They may transmit significant information or incisively shape our understanding of a complex issue but they have little, if anything, to say that pertains to the broader curricular context in which their content plays its distinctive role.

### FIRST-ORDER CONTENT

**C**OURSES WITH FIRST-ORDER content are rather like maps, whose usefulness depends upon the extent to which they resemble the regions that they depict. Undoubtedly, all maps reflect the theoretical understanding and intentions of their makers, but their success in ordering our perceptions and movements does not require our having learned how they were devised, nor the geographical theory upon which they rest. Of course, if we are curious enough we may undertake a serious study of the cartographer's craft, or probing deeper, we may question the implicit idea of verisimilitude. But in that case we would be doing something fundamentally different from simply following the map. Thus, courses with first-order content are intended to organize our thinking and refine the competency of our actions with respect to some specific purpose or goal. This purpose may be to illuminate an ancient text or increase our knowledge of a particular class of natural processes; it may be to introduce the student to programs and policies whose goal is maximizing health, industrial output or the ability to wage war. Such courses are like first-order maps which "resemble" the world rather than, let us say, second-order maps which examine the nature of map making, that is, depict the several features of the curriculum within which they are set. Thus, the professor of literary criticism does not have to contend with the question—assuming it could be plausibly framed—of whether his work is "the same" or "different" from the investigative activities of the professor of chemistry. The accuracy and value of his analysis of a work of

literature in no way depends upon the place of his course with respect to those in the fine arts or the sciences.

Nevertheless, there are aspects of first-order content which require consideration. The notion that courses of this type are like maps which bear an assumed likeness to the regions which they represent requires further comment. It is conceivable that maps depicting the same region may differ significantly and yet be sound and useful maps. Maps of different regions will clearly be different but how they may systematically cohere is also a problem. Furthermore, the inhabitants may possess their own account of the place they occupy which is at odds with the renditions of an alien geographer. Now there is a sense in which, comparably speaking, the student comes to the

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course in chemistry or moral philosophy armed with indigenous and exclusive visions of man and nature which, like first-order curricular maps, are believed to "resemble" the world. It would be foolhardy to ignore the role played by the electronic and cinematographic media in shaping her or his moral and philosophical outlook. The disheartening claim that "our students don't read" is less a symptom of their intellectual ankylosis than of the fact that the higher curriculum is not a dominant source for inquiry into problems of individual and social existence. The traditional view that what we have called "first-order" content may critically revise the roughly hewn "pre-scientific" or "unreflective" attitudes and beliefs of everyday life seems no longer tenable. The student is assailed with bewildering interpretations of the human condition drawn from ethnic folklore, popular sociology, lurid occultism, animadversions to "the bankruptcy of western rationalism," etc., which have brought the adequacy of first-order content into question. In such a climate a course of second-order content may well have the merit of making both student and teacher sit back and take stock of the value of the educational enterprise in which both are taking part.

The first level of reflection sends us to the dictionary to enquire what it is that each of the sciences and each of the humanities takes for its subject. Perhaps from these it will be possible to extract a definitional element which will allow us to see the relationship. Thus Prior [1] in

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searching for just such a common element among the various types of work usually regarded as humanistic sees them as united in their concern with "the human responses to all forms of experience and therefore primarily with those aspects of human experience 'that cannot be resolved into either natural processes common to all men and animals or into impersonal forces affecting all members of a given society'" [2]. As a starting point for a definition of science, Prior takes Nagel's claim that "it has been the perennial aim of theoretical science to make the world intelligible by disclosing fixed patterns of regularity and orders of dependence in events." [3]. On the one hand, the sciences are concerned with lawful regularities and objective facts, while on the other, the humanities are concerned with values, indeed with the values that may ultimately shape science.

## SECOND-ORDER CONTENT

PRIOR'S BOOK, "Science and the Humanities: An Essay in Definition" is an excellent example of a second-order curriculum map in the making. His overall position is that though the sciences and the humanities may share certain characteristics, they are in the most fundamental sense unalterably different. There can be no question that we need to delineate the essential ways in which they differ but this cannot be done by studying the persons and thought of scientists and humanists—there is altogether too much variation and irrelevance in that respect—rather must we concentrate on the characteristic properties of their typical productions. On the one hand, these are value-neutral descriptions of states-of-affairs; on the other, value-laden representations of the actions and inner states of individuals. The scientist's effort is to establish general natural

regularities on objective evidential grounds; the humanist deals with the unique, personalized vision of the human mind. Excising the polemical content of Prior's analysis, we are left with a second-order map, for his account of properties and products contains statements *about* science and the humanities and he assumes that there are such entities, with their own inherent characteristics, which can, indeed *should*, be demarcated.

Prior's "map" is a typical, initial (often impassioned) response to the science-humanities and this not only from students—deans, department heads and the like hang onto to it for dear life! But the student needs to be made aware that (a) we already have such a "map" in the deeply rooted attitudes which we have already acquired, perhaps unconsciously, along with our first-order learning, and (b) that there are alternative maps. Discussion of Prior's map should raise questions about his basic assumptions and his suggested characterizations. For example: is his notion of a "product" well defined? In one place he asserts that the mental processes that lead to theories are the products of science, in another it is the theories themselves. But what of the physical products and instruments—the cloud chambers, vaccines or bombs? Similarly, with sonnets and symphonies, treatises and tapestries as the products of the humanities, we have a collection so diverse and confusing as to make his concept of "products" incoherent. He assumes that there is a single, unified "Science" and an intrinsically unified "Humanities" which may be delineated by their inherent characteristics. But the gaps between the sciences themselves may be as vast and puzzling as that between the sciences and the humanities. Moreover, the relationships between the sciences may not be analogous to those between humanistic disciplines, a unified scheme of which, in spite of Foucault [4], Cassirer [5], and Langer [6], is still far on the distant conceptual horizon.

With such considerations the course should persuade the student of the importance of examining his own, and other, second-order maps and make him aware of the diverse complexity of the issues. It brings us to the point where a limited survey of historical perspectives is profitable. This allows the student to follow the salient views of the recent past as they achieve their contemporary form and heightens the credibility of the problem of showing the pattern of its development.



## AN ONGOING DEBATE

C. P. SNOW'S Rede Lecture in 1959, "The two cultures and the scientific revolution," seems to have served as spark for much of the discussion of recent years, some of which has been more inflammatory than illuminating [7]. Yet the Snow-Leavis controversy is but a contemporary manifestation of an ongoing debate, and it is useful to back up a century or so and listen to T. H. Huxley and Matthew Arnold discussing the same issues. In delivering an address [8] at the opening of Sir Josiah Mason's Scientific College in Birmingham on October 1, 1880, T. H. Huxley took the opportunity of defending the stipulation of the founder that no provision should be made for "mere literary instruction and education." He noted that the introduction of scientific education had been continually resisted by traditionalists—"Levites in charge of the ark of culture and monopolists of liberal education" he called them—who believed in the efficacy of classical education, and by the practical men, who worshipped their own god—the rule of thumb—who had "been the source of past prosperity" and would "suffice for the future welfare of the arts and manufacture." The latter he regarded as already defeated by the evidence of the value of science to popular progress, but the former he acknowledged to be

ties and its limitations"), he dissented from the assumption that literature alone was able to supply it. He took the traditional viewpoint to be a carry-over from the Middle Ages when the Latin tongue was the entrance to all knowledge surviving even when the medieval worldview—"conclusions in accordance with ecclesiastical decrees" "deduced from the data furnished by theologians"—was quite discredited. Loudly as he acclaimed the victory of the Renaissance humanists over this superstition, he deplored the fact that their revival of classical studies had become ossified into a reactionary resistance to the spread of "natural knowledge," the distinctive feature of the times, the shaping of the present life and hope of future prosperity [9].

Huxley was taking issue with Arnold's claim that the proper intellectual "outfit" for the nations of the civilized world was "a knowledge of Greek, Roman and Eastern antiquity, and of one another." Arnold complained [10] that Huxley took this to mean "literature" in the narrow sense of "belles lettres" and joined him in condemning "superficial humanism." In proposing that we should learn all "the best that has been thought and said in the world," Arnold would certainly have included "the great results of the modern scientific study of nature" with literature and art. However, he demurred at the claim that

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less easily extirpated, dug in as they were in the trenches of Latin and Greek and the foxholes of Philosophy. Huxley held that real culture could be attained at least as effectually by a purely scientific education as by an exclusively literary one and that the discipline and subject matter of a classical education were of too little direct value to be worth the time of the student of physical science. Agreeing with Arnold that the essence of culture is "a criticism of life" (that is, as he later put it, "a complete theory of life, based upon a clear knowledge alike of its possibili-

ties and its limitations"), he dissented from the assumption that literature alone was able to supply it. He took the traditional viewpoint to be a carry-over from the Middle Ages when the Latin tongue was the entrance to all knowledge surviving even when the medieval worldview—"conclusions in accordance with ecclesiastical decrees" "deduced from the data furnished by theologians"—was quite discredited. Loudly as he acclaimed the victory of the Renaissance humanists over this superstition, he deplored the fact that their revival of classical studies had become ossified into a reactionary resistance to the spread of "natural knowledge," the distinctive feature of the times, the shaping of the present life and hope of future prosperity [9].

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was his rough enumeration. With these powers certain cultural pursuits are associated, as when in following the power of knowledge we acquire certain information. But beyond them lies the desire to relate the different powers and their pursuits to one another and "in this desire lies the strength of the hold which letters have upon us."

#### HUXLEY-ARNOLD UPDATE

**A**RNOLD DISTINGUISHED "instrument-knowledges" as those which cannot be made to serve this integrative instinct directly though they lead on to other knowledges which can so serve. The natural sciences seem to stand for him on this second tier, but even when they bring us to what Huxley calls the great "general conceptions of the universe forced upon us by the physical sciences," they still fall short and because the knowledge they give is not put in relation to our sense for conduct or beauty, because it is untouched by emotion it becomes after a while unsatisfying and wearying. Arnold is not concerned with the social issues nor does he explain how the development of culture as he sees it is to be articulated, but on one thing he is emphatic—that the threatened dominance of science would be stifling and stultifying.

It is a debate conducted with the amplitude of Victorian prose and a generosity of spirit that later encounters often lack. Arnold calls Huxley "a man of science who is also an excellent writer

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and the very prince of debaters"; Huxley says he is "too well acquainted with the generous catholicity of spirit, the true sympathy with scientific thought which pervades the writings of our chief apostle of culture" to identify him with the opinion that a liberal education consists only in a little Latin and less Greek. It is a far cry from Leavis' "as a novelist Snow doesn't begin to exist" which betrays, as Snow retorts, "a psychological compartment" in which he has no desire to join him. But fireworks aside, the Snow-

Leavis debate is little more than an updating of the Huxley-Arnold. Leavis does not speak of powers but of discourses or languages, for which literature plays the same integrative role as being the best exemplification of discourse. Snow's claim is that the humanist has ignored the social condition of man by focussing his attention on the tragedy of the individual and has thus become insensitive to the needs of the very "humanity" he claims to represent. The scientist by contrast, having "the future in his bones," is basically optimistic even though he is just as sensitive as the humanist to the plight of the individual. It is when Snow claims that the scientific edifice is the most beautiful collective work of the mind of man that he really drives Leavis up the wall. Leavis' reply, in effect, is that science is not self-validating and gives no entrée into what is ultimately valuable to man. The ultimate is seen by all four debaters in what might be called humanist terms for all are as remote as could be from the medieval view of man "sub specie aeternitatis." Arnold and Huxley in the dawn of the post-Christian era rejoice in the liberating influences of experience and scientific knowledge respectively—"is it so small a thing to have enjoy'd the sun . . . ?" [11]. Snow and Leavis a century later are flowers of the anthropocentrism that was budding in the Victorian age, children of a world view held together by Coulombic forces rather than compassed about by the battlements of eternity.

Snow is sometimes read as if he were concerned with the synthetic vision of culture, and one of the aims of such a course as this is to elucidate his intention. Is he a Colossus with one foot in the world of physics, the other in the world of the novel and his hands in the realm of affairs and politics or is he a "portent" (the very word has a hollow sound) as Leavis claims? More important is it to ask the question of whether he is trying to find a unified outlook or whether, in spite of some indications to the contrary, he is advancing a view of culture in which the scientist is in the ascendancy. What is undoubtedly new with Snow is his preoccupation with power and the realization (absent in early writers of scientific background such as H. G. Wells) that the decisions of the modern world cannot be made apart from an understanding of scientific advance. It is the drama of man in power—rather than man as creature or man's tragic condition—that animates Snow's novels and gives them an interest

that carries one through their somewhat stilted conversations. It is interesting that Martin Green (whose "Science and the shabby curate of poetry" [12] is perhaps the most balanced and perceptive reflection published on the two-cultures controversy) sensed this in his Cambridge seniors when he was there as an undergraduate in the latter '40's. "They could believe," he says, "in the beauty and value and use of power. Oxford and Cambridge are full of that awareness of power to come."

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#### NOTHING INEVITABLE

**I**F THE "OPENING GAMBIT" of this course is to make the student aware of the complexity and seriousness of the problem and the "middle game" to deepen this by historical insight, it must not be thought that the "end game" will be a neat and ingenious solution in which white is to mate in three moves. For there is nothing inevitable about the moves in such a discussion, nor even an existence, let alone a uniqueness, proof of a solution. There are, of course, plenty of avenues to explore as the list of references given below (and it is a very abbreviated one) will show. Bronowski's synthesis can lead to the discussion of the internal and external ethics of science [13]; Huxley's little book makes for some interesting comparisons between his and his ancestor's viewpoints [14]. Specific humanistic subjects can be taken up as in the booklets of Levin [15] and Thorpe [16], or the general question of culture can be pursued down a variety of avenues in the writings of Eliot [17], Tillich [18], Marcuse [19], and Steiner [20].

In short, such a course can be both broadening and deepening to student and teacher alike, for preeminently in such a second-order area the interactive nature of learning can be enjoyed to the full. Because the issue is of central importance,

it is a topic which can be returned to again and again and which, if the authors' experience is anything to go by, continually provides fresh impressions and insights. □

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information by a commission of high academic standing.

It was observed that the students are able to cope with the problem of material written in a foreign language, and given the characteristics of the system, it is possible to help them whenever they need it.

As far as the student-professor relationship is concerned, the fundamental characteristic of the system consists in, completely eliminating adverse stimuli and substituting them by positive reinforcement. Incompatible conducts are also suppressed by simply not stimulating them. During our three experiences, there was not a single authority problem, on the contrary, magnificent relationships were developed.

## RECOMMENDATIONS

**I**N VIEW OF THE pressing need to face the academic and political problems of our Chemistry School and the country in general, we propose to give priority to the teaching system, taking as a basis the general principles indicated in this document. Said system must constitute the basic platform and must generate the fundamental infrastructure to establish the general project for change in ChE education within a period no longer than 4 years.

Starting from an investigation of needs in terms of the activities of a ChE, define what aspects of science are most important for the development of Mexico and develop a basic structure of knowledge to be taken by students in their first two semesters of college. Consequently, the resources should be distributed preferably to those areas requiring more development and depth according to the peculiarities of our situation.

We consider as the basic platform, a first semester with General Physics, General Chemistry, Mathematics and Laboratory. In this platform, our basic academic activity must be the integration of these subjects with the activity of a ChE.

In order to develop the basic platform, we must integrate an "Academic Commission" formed by representatives from each area of the country, with a high academic standing; with nationally recognized researchers and specialists working as consultants.

The experience and results achieved by this commission during the first year of work, should permit us to create, one year in advance, the

academic commissions for each area of the country, in order to generate the new plans, programs and materials for every area.

It is necessary to form a "Technical Group" whose task will be to work in close contact with the Academic Commission, in order to centralize the evaluation of the learning process for all the groups participating in the first level of basic science. This Technical Group should gather the greatest amount of information possible concerning the current distribution of resources in a ChE school, as well as their characteristics, so that the Academic Commission can use this information, for a more logic development and implementation of the teaching methodology and the material associated with it, according to our current conditions in a university and in the country. □

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