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SCIENCE DIRECT®
Materials and Design 26 (2005) 313–319
Materials & Design
www.elsevier.com/locate/matdes

Contextual perspectives on education in materials science and engineering

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Received 5 January 2004; accepted 7 June 2004
Available online 15 September 2004

Abstract

From an inside point of view, the concept of a ''unified science of materials'' might appear to be quite natural in its own right, as it were. However, considering the fact that science in general is practiced by humans in a social environment, it should be warranted to examine materials science also from the humanistic and sociological perspectives, as well as against the background of current thinking on the development of sciences. By this means it would be possible to establish rational principles for education in materials science and engineering not only for specialists but also for designers and manufacturing engineers. The present review deals with issues of integration of sciences versus specialization, ideas about a comprehensive theory of materials, internal and external driving forces for scientific studies, engineering practice, professional competence, and educational consequences with an emphasis on understanding.
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Keywords: Cultivative education; Engineers' application; Knowledge and competence; Thought style; Postmodernism

1. Introduction

In the present context, science may be considered, in principle, as a means of producing information and knowledge. Its ultimate aim is to improve the understanding of the nature of perceived phenomena. Such scientific work is motivated and driven by forces ranging from curiosity to needs to solve specific problems.

For the understanding at hand, it is important to realize that scientific activities take place in a human environment. This means that they are influenced by social and psychological conditions. The same is true for the use and application of the knowledge produced as well as its understanding.

Hence it seems warranted to regard materials sciences as parts of systems that also include components of a sociological and psychological character. The same is even more true for materials engineering. In principle, therefore, the following deliberations relate to the concept of materials science and engineering. MSE, established at universities and polytechnical schools in many countries.

2. A parts-and-wholes syndrome

Ever since the term ''materials science'' was introduced some 50 years ago, it has been challenged from time to time as a unifying concept encompassing a number of traditional materials sciences. Among other things the critics have claimed that each of the latter has its own characteristics, which should make them conceptually independent. The advocates of the unifying concept defend their case by referring to the existence of common features within the family of materials sciences.

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doi:10.1016/j.matdes.2004.06.016

Apparently, this is a conflict between people who are inclined to perceive similarities, in contrast to those who focus their attention on differences. These are general attitudes which appear under many circumstances. Actually, there is a saying that humanity is divided into two parts, according to the emphasis they place on similarities and differences.

In the case of materials science, this dichotomy relates to a corresponding polarization of views on parts as opposed to wholes, i.e., separate materials sciences versus one single science for all materials. In fact, this is a syndrome that is well known to social psychologists, In order to explain various worldviews, they refer to the parts-and-wholes dichotomy coupled to differentiation with respect to determinism and free will [1].

This typology reflects ingrained values that determine people's attitudes and behaviour in general. This is something that cannot be changed easily. However, it would be enlightening for all parties involved if they could become aware of such grounds for their views on the issues in question. This might possibly lead to an enhanced understanding of the relative importance they attach to similarities and differences.

To some extent such an analysis may be a constructive part of considerations of proposals for establishing departments of materials science and engineering. This relates, among other things, to decisions about boundaries between subjects of the curriculum that should and should not be included for scientific reasons. In addition, this analysis could serve as an introduction to students who need to know why there is such a discipline as materials science.

The general mental inclination toward a domination of differences, as compared with similarities, in the perception of the nature of materials may at least partly explain the reluctance shown in some quarters to the establishment of a materials science encompassing virtually all materials. However, there are, of course, also other mental or psychological reasons for specialization within the vast field of materials science. In particular at the level of industrially oriented research on different materials, such as metals, ceramics, and polymers, it is hardly possible for the individuals assigned to each material to keep all of them in mind effectively at the same time.

Obviously, this mental conditioning is paralleled by economic and organization reasons for specialization among possibly interesting materials. Taking all of these various determinants into account, it seems as if the coordination of materials into one single science should not be misunderstood as an operational principle for comprehensive research in the entire field of materials. The concept in question can rather be regarded as a construct made for the purpose of exploitation of the possibilities of developing and utilizing theoretical methods of understanding phenomena that different materials may have in common.

One illustrative example of this role of materials science and engineering is the case of viscoelasticity. In practice, this term is most commonly used to characterize time-dependent deformation of polymers. While in a continuum-mechanical sense it is also applicable to metallic materials, the alternative concept of creep is more useful for practical purposes in the latter field.

As a consequence of this situation with respect to differences, it appears that in the professional perspective there has to be a distinction among materials scientists and engineers between specialists on, say, polymers, metallic materials, and ceramics. It should perhaps be noted that this is not due to conservatism or orthodoxy but is an adaption to contextual conditions in both science and engineering of materials.

3. Internal and external determinants

Some sciences or disciplines are considered to live their own life, independent of external conditions, while the development of others appears to be driven by outside forces that may be called social. Applied to the case of materials science, there is no clear distinction between a domination of either internal or external causes of its emergence. Features of both kinds can be found in the arguments for and against an integration of various specialized disciplines into a unified materials science.

Those who are inclined to take a holistic view of the world seem to refer, consciously or unconsciously, to an assumed common process of development of the various different sciences of materials. On the other hand, they sometimes base their arguments on the strength of external forces, such as the need for common principles for assessing the specific engineering properties of materials.

The same seems to be true for their antagonists who prefer to stress differences between different materials. This creates a particular dilemma in the debate between the opposed parties when one of them focuses on the internal aspect, while the other emphasizes the external one. Their respective conflicting standpoints cannot therefore be contested simply by a constructive confrontation. What then remains would be a dialectic process for solution.

A related dichotomy is that of theoristic versus empiristic approaches to the issue in question. According to the former, the basis for a scientific examination of a certain reality is a general theory that enables a systematization and explanation of all phenomena within the reality considered. The point of departure of the latter is separate observations from which a theory may emerge by an ordering process. Thoughts about integration of different

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