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CERAMIC EDUCATION Ludwig J. Gauckler (ETH, Zürich)

Ceramic Education has to be discussed in context with the broader subject of education in Materials Science and Engineering.

The field of Materials Science and Engineering of today is a well established major discipline, still in a growing and expanding situation. It is one of the modern engineering disciplines, ranging from basic science to applied science and engineering.

The importance of ceramics as a special category of engineering materials and their vital role for the quality of life has been recognized a long time ago. However, it is only since a few decades, that ceramic materials were found to be also important for the national defense, economic security and competitiveness of a nation. Quite recently, also oecological aspects concerning the production and the use of materials have gained in recognition, besides structure, properties, processing and performance relations. This aspect was brought up by non-materials people first and is now increasing in importance to materials scientists and engineers too.

Materials science and engineering is multidisciplinary in respect to those concerned with the production and development of materials but also in respect to their oecological importance for society.

WHO SHOULD BE EDUCATED IN MATERIALS SCIENCE AND ENGINEERING ?

Materials Science and Engineering is a multidisciplinary field relevant to most of the areas of society. Besides the specialists concerned with the production, the development and the recycling of materials on all levels from craftsmen, engineers and to the scientists, there are many non-specialist groups having need to be trained and informed about materials. Therefore, education about materials is needed also outside the traditional engineering and science groups. Many non-technical people in society like politicians, journalists, bankers as well as students at the pre-university level in the colleges should know about materials.

How and how much these different groups in society are educated concerning materials differs widely in different countries. However, it seems a common feature, that most emphasis is put in all countries on the education of the "specialists" and much too little on educating the non-specialists. This is particularly true for students in the colleges who only get very little knowledge about materials in their physics and chemistry courses. Therefore, most of the college graduates do not know too much about materials and never will know in their further life. In consequence, materials engineers lack the recognition in society and therefore, in self-confidence.

This situation can only be changed on the long run by introducing more materials-related courses and examples in the basic physics and chemistry classes in colleges. Physics and chemistry courses could make the link between the basic needs of human mankind, the application of materials, as well as the natural resources we use for production of materials.

Introduce materials related examples in basic physics and chemistry courses on college level !

EDUCATION FOR MATERIALS SCIENTISTS AND ENGINEERS

Concerning education of materials scientists and engineers, the following questions can be rised: How should we educate ? How much specialists, how much generalists our graduates from universities and engineering schools should be ? How many of them are needed in society ?

Ceramic education, as well as more general, materials science education takes place in Europe on various levels.

Craftsmen are educated after leaving basic schools at the age of 16 parallel to their training on the job in craftsmen schools.

Higher educated students leaving gymnasium at the age of 17 may attend one of the "Ingenieur"-schools to get a training in one of the materials science and engineering disciplines, e.g. in ceramics. In a recent publication the European Ceramic Society summarized most of the information about the "Ingenieur"-schools in Europe. These engineers are trained during 3 to 4 years including at least 1 year practical work in industry. Another group, leaving college education at the age of 19 enters the universities, with the aim to get a university diploma degree after 4 to 5 years. A minority of these Diploma Engineers will carry on research towards a Ph.D. degree. The curricula range from general materials science and engineering to the more specialized metallurgical and polymer oriented fields. Very seldom special ceramic engineering curricula are established at the university level in Europe.

This systematic in education may vary from country to country in Europe. A larger difference can be recognized in the materials education of craftsmen and applied engineers between Europe and the United States. In Europe systematic education of these groups takes place in schools parallel to their training on the job in close relation to the industrial needs.

WHAT SHOULD WE EDUCATE ?

At university level this question poses a special challenging dilemma for professors having the aim to educate both, engineers as well as young scientists. Engineers should utilize their aquired knowledge to solve complex problems in limited time, with incomplete information. Engineers should be trained to be result-oriented. They have to come up with more than one solution in the framework of constraints an engineering task puts to them. An engineering task has therefore many solutions.

Scientists should be oriented towards understanding the nature of the physical world. Very often their questions have only one answer.

Both attitudes can be unified in an almost ideal way in the education of materials science and engineering. Materials education should be based on:

- alertness to industrial and society needs including the problems of oecological impacts of materials and the use of their resources
- an integrated view of engineering aspects and the fundamental basics of physics and chemistry
- a good fundamental knowledge in structure, properties and processing of materials
- a good training in the specific materials-related basic topics such as mechanical, electrical and chemical properties, thermodynamics, phase transformations and reaction kinetics.

Materials specialists represent the bridge between the demands of other engineers and designers who formulate specifications to them derived from the basic needs of the society. In this function, the materials specialist fulfils his engineering role and is concerned to satisfy needs. He reacts to the market pull situation. An example would be the building industry or the electronic industry. The technology push situation arises in case a materials scientist's new understanding leads to new solutions or new devices made up by new materials or new combination of materials. A good example are the superconducting cuprates.

Education of materials scientists and engineers should emphasize both approaches. Which approach is suited best for a particular individuum becomes apparent only during a longer period of time in which a student is exposed to both approaches.

HOW SHOULD WE EDUCATE ?

Everybody who had the opportunity to watch young children at the age of 5 to 10 getting in touch with a personal computer will realize that <u>motivation</u> is by far the most important driving force for learning. High motivation in education of materials science and engineering starts with questions such as: What can a materials specialist do to improve our lives ? What can I contribute to solve our society's problems ?

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The next step is to lead from practical engineering problems and practices to the basic principles of natural sciences. This sequence is also natural to young children in case they go beyond their first computer games and start their own programming on the PC.

R. Roy pointed out this new paradigm in learning science and engineering since several years.

To answer fully the question, how should we educate, all results and practices of modern education should be used. In respect to materials science and engineering a wide variety of curriculae, visual aids, videos, models for lab courses and experimental facilities are available today. It seems to be a fact, that there are much more helpful guidelines and aids available than we use today. This is due to limited time the lecturers spend in preparing their courses. Frequent assessments of the lecturer's performances are helpful in improving their didactic capabilities.

HOW MUCH SPECIALISATION, HOW MUCH GENERALISATION ?

Should we produce materials scientists and engineers who are specialists (e.g. in one of the materials fields like ceramics, metals, polymers, etc. ?) Or should we produce more generalists ?

It seems to me there is no simple and general answer to this question. Industry is looking for people who solve short term problems in short time at minimum costs. For these questions, specialists would be suited best. On the other hand, the needs of industry are shifting so rapidly, that it is unlikely that a specialist will work in his area very long. Very soon he has to solve a new problem.

In addition, the engineering problems are more complex than pure scientific questions and therefore, generalists are of advantage.

Universities however, are looking for people who can be at the forefront of their specialized discipline. This means that specialists rather than generalists would fulfil such requirements better in research.

For education, generalists with practical experience as well as excellent basic science background are needed.

SUMMARY

Ceramic education should be continuously reformed and adapted to the requirements of modern technology and to the concerns of our society. Therefore its multidisciplinary character has to be extended increasingly to the environmental and biological sciences. This is of paramount importance e.g. for the understanding and development of composite materials where the interplay between the different materials is but one important aspect.

Modern ceramic education should consider much more the practical importance of materials and especially their processing with all the problems when starting from the raw materials. This is true also for the basic sciences like chemistry and physics, which are taught sometimes too theoretically and without putting some emphasis on application of the principles in materials properties and application.

This is somewhat in contrast to the present trend in engineering curricula in general where the move is toward more basic, theoretical science and away from the applied sciences.

One reason for this is that students assume, that it is more prestigious to be a researcher rather than an engineer.

A ceramic engineer should know how to design with materials having specific properties and be able to work out a process for fabricating such materials using the principles of ceramic science and processing/structure/properties relationships. The reality is that frequently processing and application of properties (design) are more or less eliminated from curricula. The result is that a graduate in ceramic science will not know how to use and apply basic science to solve problems until he has got an on the job training. The unpopularity of laboratory courses has added to this. Synthesis and processing are the main shortcomings in the present ceramic education.