White Paper on
"Design" in Ceramics, Materials, Metallurgical and Similarly Named Engineering Programs

<u>Background</u>

ABET EAC criteria for the 2005-2006 academic year and following years involves "design" in several ways:

<u>Criterion 3. Program Outcomes and Assessment</u>

Engineering programs must demonstrate that their students attain:
. . .
(b) an ability to design and conduct experiments, as well as to analyze and interpret data

(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
. . .

<u>Criterion 4. Professional Component</u>

. . .
(b) one and one-half years of engineering topics, consisting of engineering sciences and engineering design appropriate to the student's field of study. . . Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet the stated needs.
. . .
Students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints.

<u>The Program Criteria for Materials, Metallurgical and Similarly Named Engineering Programs:</u>
. . .
the program must demonstrate that graduates have . . . the ability to apply and integrate knowledge from each of the above four elements of the field [structure, properties, processing, and performance] to solve materials selection and design problems . .

Introduction

Understanding and interpreting design as specified in ABET EAC Criteria 3 and 4 vary widely among ABET leaders, program evaluators, college and university faculty and department chairs involved with materials programs. A consequence of this diversity in points of view is that it is difficult to devise meaningful and challenging capstone design experiences for students in materials programs that will with some consistency satisfy program evaluators. This topic and the ABET accreditation process in general were discussed by the chairs of Materials departments attending the May 5-6, 2005, University Materials Council (UMC)[1]. Based on these discussions, this whitepaper has been written to develop a more consistent and constructive interpretation and understanding of "design" in the context of ABET EAC criteria and of objectives, outcomes, and resources of the nation's undergraduate materials programs,.

In discussing ABET accreditation criteria and procedures particularly as they apply to "design," UMC members noted the great diversity in the nation's materials programs, with many now including some or all of the following areas: biomaterials, ceramics, electronic materials, metals and polymers, along with nanotechnology and computer simulation and modeling. In addition, materials design incorporates both "design of" and "design with" materials, which makes these programs different from those in most other engineering disciplines. These factors, along with the need to prepare future engineers for success in a global job market, warrant a broad and flexible interpretation of the ABET EAC Criteria 3 and 4 for design.

To help materials programs develop innovative and challenging design experiences that satisfy ABET accreditation criteria, the UMC offers the following proposals to TMS and NICE to improve training and guidance of program evaluators and materials program faculty.

Proposals

1. The Curriculum section of the Program Criteria for Materials, Metallurgical and Similarly Named Engineering Programs and the Program Criteria for Ceramic and Similarly Named Engineering Programs should be interpreted by program evaluators and materials program faculty involved in "design" in a broad context.

In evaluating students' abilities "to design a system, component, or process to meet desired needs" and students' preparation through a "major design experience based on the knowledge and skills acquired in earlier course work," the "design" may include: design and evaluation of a material for a specific application; reverse engineering and design improvements involving materials; design and evaluation or optimization of a materials processing method; design of a method for determining, controlling, or selecting materials characteristics or properties; or design activities that otherwise satisfy requirements in ABET EAC Criteria 3 and 4.

2. Training materials for program evaluators and faculty involved with accreditation for ceramics, materials, metallurgical and similarly named engineering programs should include

[1] The UMC is the organization of heads and chairs of materials departments, who are responsible for leading, developing and overseeing educational programs to prepare the nation's future generations of materials scientists and engineers for productive, lifelong careers.

discussion of breadth and diversity of "design" that satisfy the design requirements of Criteria 3 and 4.

<u>Further Discussion for Program Evaluators and Faculty Involved with Accreditation</u>

The proposed addition to the training materials for program evaluators and faculty in Ceramics, Materials, Metallurgical and Similarly Named Engineering Programs provides examples of possible design activities for materials students. For these types of activities to satisfy ABET EAC Criteria 3 and 4 design requirements, they must incorporate consideration of "realistic constraints" that are appropriate to the activity, for example strength, weight, cost, lifetime, and environmental impacts might be important in "design and evaluation of a material for a specific application," in "reverse engineering and design of improvements involving materials," or in "design and evaluation of a materials processing method." Realistic constraints in "design of a method for determining, controlling, or selecting materials characteristics or properties" might include the accuracy or precision needed in determining properties, economic and time trade-offs in different measurement methods, choice among different equipment available for the work, and health and safety concerns in setup and operation of the equipment. "Design of a method for determining materials properties," might satisfy the Criterion 3(b) "ability to design and conduct experiments, as well as to analyze and interpret data" as well as Criterion 4. In the materials discipline, design and conduct of experiments, "within realistic constraints," can be viewed as design of a "process" that satisfies Criterion 4 in the same way as design of a system or component, if design of the experiment has the usual defining characteristics of "design " in Criterion 4, being a "decision-making process . . . in which the basic sciences, mathematics, and the engineering sciences are applied . . . optimally to meet these stated needs." Materials modeling and simulation are increasingly important in materials science and engineering, and some design experiences may be conducted entirely through computational design of materials.

Both program evaluators and program faculty should recognize that it is the responsibility of each educational institution to insure and demonstrate that its program meets the requirements of the ABET Criteria 3 and 4 with regard to "design" and in other areas, but that the design requirements of ABET Criteria can be met in a variety of ways, which may differ widely among different programs and even for different students within particular programs.

Examples of Design Experiences in Materials

These examples are provided as a guide and are intended as projects within a design course.

1. **Participation in a broad-based multi- and inter-disciplinary team project, the outcome of which is not necessarily a materials component, system or process.** This may or may not involve an international component.   Selected examples:
    - Solar car, concrete canoe building or similar project.
    - Other opportunities are available at some institutions through student led organizations such as *Engineers Without Borders*

    (see for example, https://netfiles.uiuc.edu/ro/www/EngineersWithoutBorders,UIUCChapter/).
2. **Design, select and evaluate the application of materials for a specific application**
    - Keramos/ACERS ceramic cup or putter design competition. Details can be found at http://www.ceramics.org/membership/Keramos/2005mugrules.pdf.and http://www.ceramics.org/membership/Keramos/2005puttingrules.pdf.
    - Failure analysis of a component and development of an improved material, process, or design for the component; design of processes for heat treatment of an alloy or deposition of a thin film to control properties for a specific application; process design to control morphology in injection molding of crystalline polymers,; design of processing of polymer blends for optimum properties; design and development of scaffolds for tissue engineering; design and cost modeling for replacing a component with one fabricated with an alternative material.
3. **Reverse engineering of a component and designing a better component through selection of different materials.**
4. **Design, conduct and perform a custom project**

The students will identify a problem and propose a work plan to solve the problem.   Details of the requirements would be established by each institution but may include a proposal plan with milestones and go/no-go decision points identified, progress reports (written and/or oral), lectures and seminars on conducting and managing a research program and final written and oral reports. The "team-experience" could still be satisfied by this type of project. Examples of "team members" may include graduate students and post docs, industrial scientists and engineers, as well as the undergraduate design student. These team members could be cited or acknowledged in a thesis or report for a project that is primarily the work of a single student.

- This problem may be an engineering project in which the student(s) determine the structure-processing-property-performance relationship for a process or component.
- This problem could also involve a properly constituted and framed research problem, which may be performed during an industrial internship, a summer program, as part of a co-op or in a scientific research group at a University.
- A third possibility is a computer aided design and material property determination.

5. **Design Portfolio**

Materials science and engineering students are often involved in design related programs from the beginning of their degree program; e.g., co-op, industrial summer internships, and summer research programs.   The cumulative effect of all these experiences may exceed the achievements of the best design classes and will challenge the student to acquire knowledge appropriate to the problem.