2006-1139: DESIGN VERSUS RESEARCH; ABET REQUIREMENTS FOR DESIGN AND WHY RESEARCH CANNOT SUBSTITUTE FOR DESIGN

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Design versus Research; ABET requirements for design and why research cannot substitute for design

Abstract

The ABET Criteria for Accrediting Engineering Programs specifically requires design in criterion three and criterion four. These requirements stem from a fundamental need for engineers to understand and carry out the design process and the requirements are unlikely to change in the foreseeable future. ABET criteria do not allow substitution of research for design in an engineering program. What is the difference between research projects and design projects and why doesn't ABET allow the substitution? The objective of this paper is to review the rationale for the design requirement in the ABET criteria; review the differences between design and research; and to propose questions that can be used to differentiate between a research project and a design project in an engineering curriculum.

Introduction

Can the difference between design and research be quantifiably defined? At what point does research become design or design become research? Addressing these questions is much like examining a fine work of art. Examine a painting by a master artist. Look at the white of a lily such as those found in the painting "Carnation, Lily, Lily, Rose," by John Singer Sargent [1]. Can you truly find anything that is just black or white? The fact is there are many colors in the blacks and whites and the beauty is truly in the eye of the beholder. As with art, design is often in the eye of the evaluator. If the difference were black or white, the job an engineering faculty member would be easy. A student understands design or doesn't. There would be no measuring the degrees of understanding. However, as professionals we have learned judging a student's ability to design is far more like judging shades of gray. This paper explores many of the shades of gray with respect to the differences between design and research and proposes questions that can aid judging between a "major design experience" and an academic research project.

The ability to design is one of the measures that helps define if a graduate is truly prepared to practice engineering. It is an ability defined by the engineering profession as a "black or white" skill needed by every graduate of an engineering program. A graduate must show that he or she has had "a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints." [2] However, it is at this point that engineering educators begin to illustrate the many colors of the engineering education art.

All engineering curricula, including biomedical engineering, are required to include design as part of a student's education. This requirement is supported by the definition of an engineer as one who is versed in the practice of engineering and the definition of engineering as the art of designing.[3,4] It is required by ABET, Inc. in its engineering accreditation criteria three and four. Criterion three requires that each program "demonstrate that their students attain 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." Additionally, Criterion Four states "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." Both of these criteria support the accepted definition for an engineer and for engineering.

The design requirement is supported by the biomedical engineering education community. "Design is a cornerstone of education for both undergraduate and graduate students in bio- and biomedical engineering." [5] An Ad Hoc committee of the Biomedical Engineering Society stated that "the "Design Process" is an important component of the educational program for Biomedical Engineering students." [6] Even with the clear requirement and the support for the requirement for design there is still strong sentiment that a student should be allowed to substitute a research project for a design project. To a great extent, this sentiment falls in the category of art appreciation; what is art? What is design? What is research?

The Black and White of Design

There have been literally hundreds of books written on design. Reviewing several provides the following definitions of design:

- "Engineering design is the set of decision processes and activities used to determine the form of an object given the functions desired by the customer." [7]
- "Engineering design is a methodical approach to solving a particular class of large and complex problems." [8]
- The systems engineering process begins with the identification of a "need," "want," or "desire" for one or more new entities, or for a new and improved capability. It should be based on a real (or perceived) deficiency.[9]

While the description of engineering design varies in its wording, there is a common thread among authors. The most important point is that design is a *process* that ensures success. It is an iterative, decision making process in which the student deals with compromise and optimally applies previously learned material to meet a stated objective. It is an approach to problem solving for large-scale, complex and sometimes ill-defined systems. Most often, the student is exposed to system-wide synthesis and analysis, critique and evaluation for the first time. Design is the creative process of identifying needs and then devising a product to fill those needs. A simplified flowchart for the design process is shown in figure 1. An essential aspect of design is the engineer knows with certainty, whether or not the design meets predetermined specifications of the design. Failure to meet the specifications is a failure of the design.

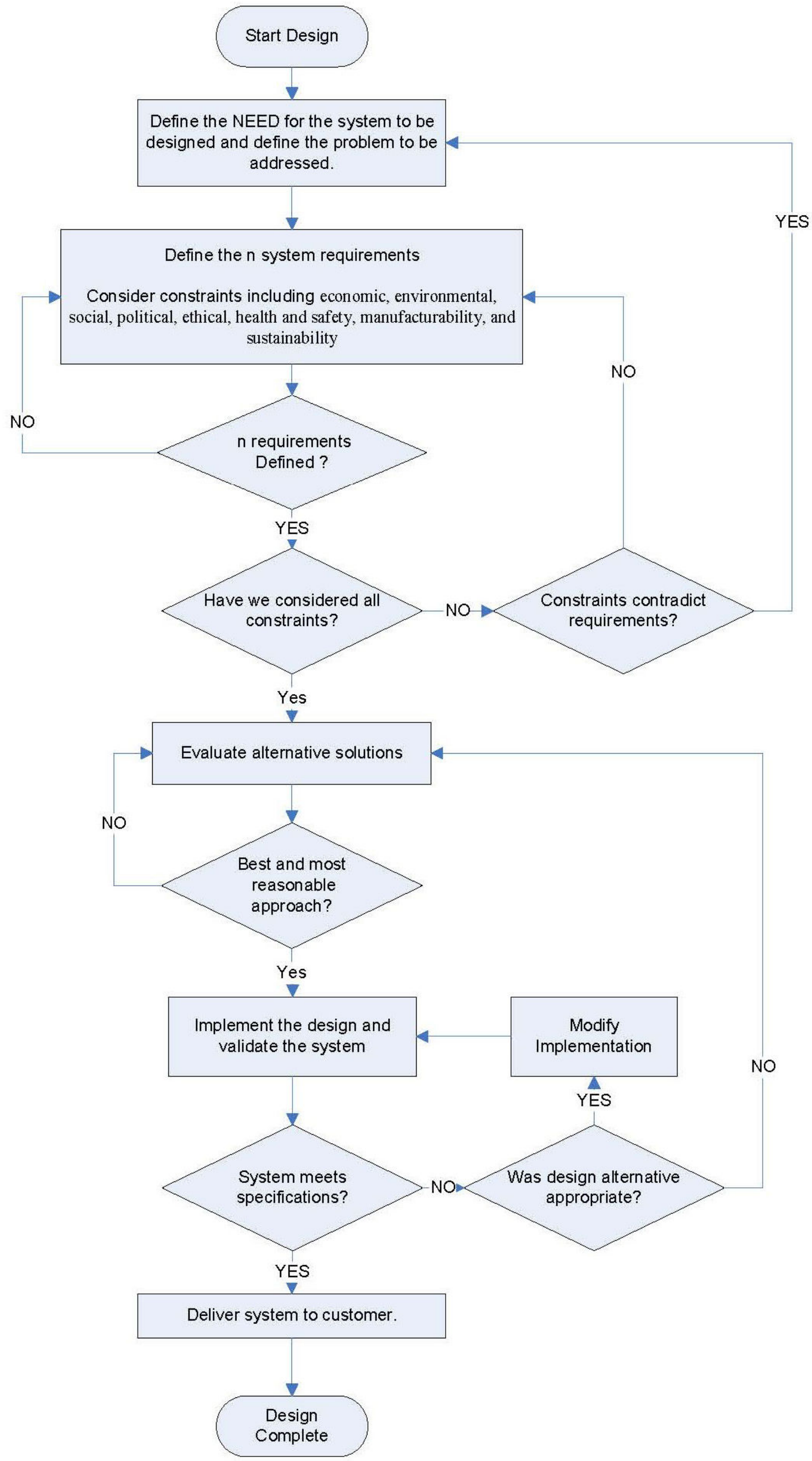

Figure 1: Simplified process flow for design

The Black and White of Research

Research is defined as scholarly or scientific investigation or inquiry. Figure 2 illustrates a simplified flowchart of the research process. Research requires the scientific method, has an open-ended goal and is exploratory, has no set specifications of results, and does not necessarily result in a product or a service.

The scientific method is defined as the principles and empirical processes of discovery and demonstration considered characteristic of or necessary for scientific investigation. The first step is usually the observation and description of the phenomena or phenomenon. Next, formulation of a hypothesis is generated concerning the phenomena. Ideally, the hypothesis is written in terms of a quantitative description that can be used to predict the existence of new observations. Finally, experimentation is carried out to demonstrate the truth or falseness of the hypothesis, and a conclusion that validates or modifies the hypothesis.[4] An essential aspect of research is there is typically no certainty about the outcome -- the hypothesis is either proved or not proved.

The Gray between Design and Research

"Design is NOT research, which may be defined as "a careful investigation or study, especially of a scholarly or scientific nature." A design task may require research to accomplish a task, but it typically involves the integration of knowledge, not the creation of knowledge." [10] Design is different than research. Design considers alternative solutions by selecting the optimal solution with a fixed goal or specifications in mind. Design often results in a commercial product being developed. Research has an open-ended goal and is exploratory, with no set specifications in mind, and does not necessarily result in a product or a service.

However, a major research project will likely require one or more design projects to carry out the experiments. Each of these design projects in a research umbrella can be carried out as described in the section on design. For example, a significant instrument or process may be a critical component of an overall research project. Oftentimes, the major hurdle in carrying out a research project is the creation of a transducer that allows a new experiment to be conducted. Creating that transducer may be a "major design experience" for the engineering student who does the development. This can be an outstanding design project for the student and the faculty who advances their research project. However, this type of design project has many pitfalls.

Design or Research?

When does the research project include significant design and when does a student design project rise to the level of a "major design experience?" The following questions may suggest the answer:

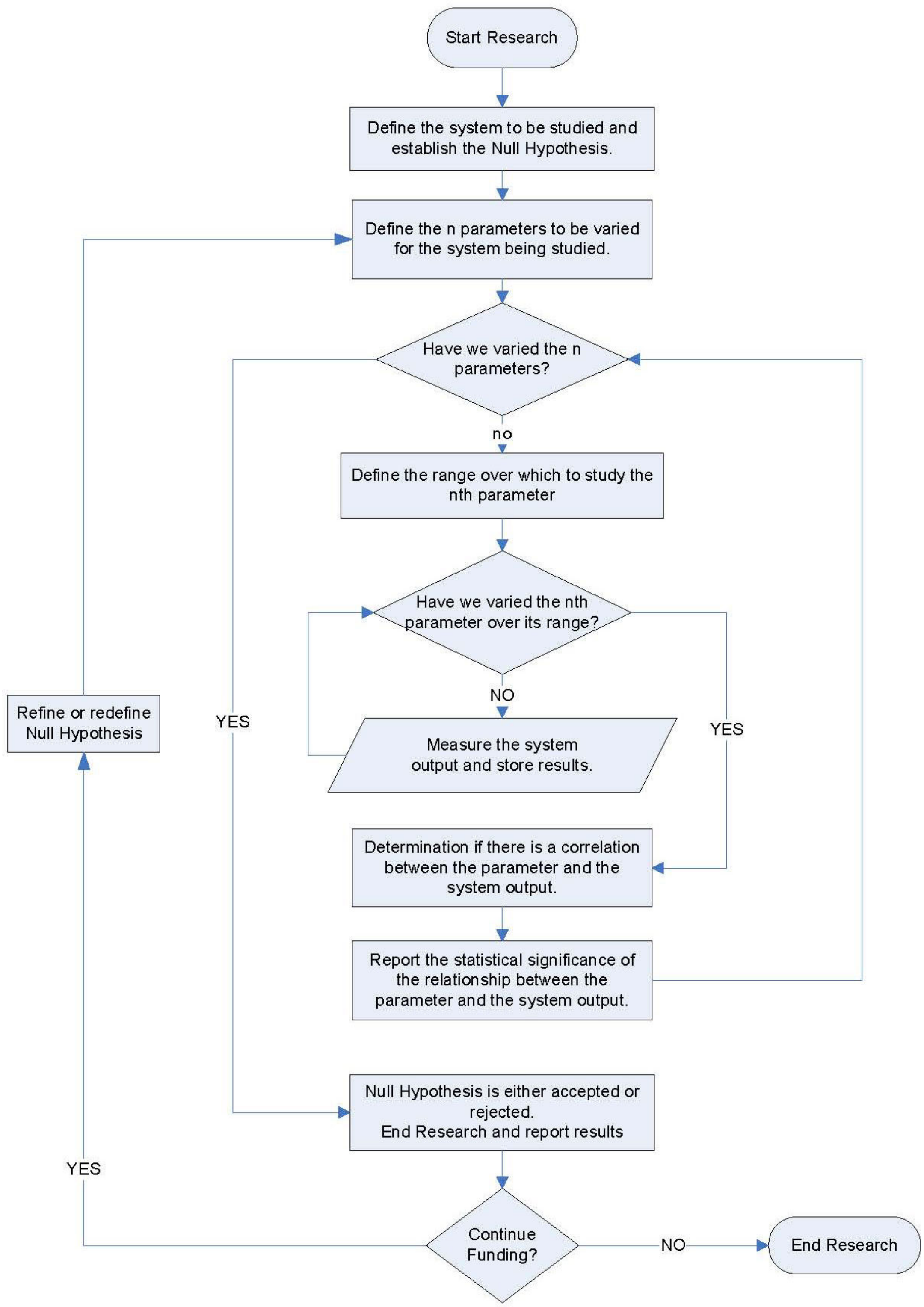

Figure 2: Simplified process flow for Research

- Is there a formal design process?
- Has a need been clearly defined?
- Has the problem associated with the defined need been clearly defined?
- Are there clearly defined specifications?
- Has there been consideration of realistic design constraints, examples include:
    - interaction between living and on-living materials and systems
    - requirements imposed by the FDA
    - economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
- Have alternative approaches been developed?
- Are alternatives evaluated and the preferred alternative selected based upon the design constraints?
- Has a design been implemented?
- Has the design performance been verified

If the answer to a majority of these questions is no, one must question whether there has been a significant design experience.

Conclusion:

Relatively succinct definitions have been presented that differentiate between design and research, and many will continue to believe that research is a reasonable substitute for design. Those beliefs will continue even though the engineering community has been emphasizing design content in engineering education and it has been required by ABET for over 40 years.[11] The reason appears to be the academy's emphasis on research and the fact that it has been an integral part of engineering education for an equally long time. In 1968, the ASEE stated "In engineering colleges it is vital that there be the fullest possible integration of research with the educational purpose of the university." [12]

Although research experiences give students significant educational benefit, they do not replace the skills learned through a rigorous and disciplined design process. The outcomes of design are vastly different than those of research. Those differences make it necessary to differentiate between the experiences and ensure students receive the education necessary to function as an engineer in today's society. While it is clear that design is an absolute requirement of an engineering curriculum, the shades of gray will continue to challenge the engineering educator and the separation of design from research will be contentious.

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