

Special Session: Learning Design Thinking Using Engineering Case Studies

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Abstract — The dominant mode for teaching engineers about design thinking is project-based learning. We give students things to design - individually or in teams, and then evaluate the products they produce. But another way to learn about engineering design is to study real-world examples. Case studies provide one way to do so. Cases have been used in schools of business for many years; the case study method is the primary approach for MBA programs at schools like Harvard Business School and the Darden Graduate School of Business at the University of Virginia.

In this special session, we will examine several case studies used in a course *Fundamentals of Design Thinking* taught at the University of Virginia. These focus on individual engineers and architects as well as the companies they have founded: Dave Kelley (IDEO), Dean Kamen (DEKA), Oliver Kuttner (Edison 2), Bill McDonough (William McDonough + partners), and Evan and Eric Edwards (Kaleo). The cases concern the personalities and motivations of the key players in each organization, the structure and culture of the organization, the types of products designed, and their impact on contemporary society.

We will illustrate the use of cases with two examples: one focused on a successful company and the other on a particular product design. Then we will briefly discuss cases concerned with ethical issues, product liability and intellectual property.

Keywords — design thinking, cases and the case study method, engineering innovation, famous engineers and architects, entrepreneurship, engineering ethics.

I. INTRODUCTION

Design case studies in engineering have been used sporadically since the 1950s. Faculty at Stanford University produced a number of these early cases that then became part of the American Society for Engineering Education (ASEE) case library. Cases have since been used in a number of engineering disciplines; some with great success, others less so! A primary focus of previous work has been on ethical

issues in engineering practice and on critical failure events such as the space shuttle Challenger explosion. We will provide an overview of the resources and use of cases in engineering education, and provide examples of best practice using the case method in both engineering and business contexts [1, 2].

Design thinking is a current buzzword in many fields, but of course, engineers have always done design. It is the fundamental mode of thinking in engineering. A new course on the *Fundamentals of Design Thinking* has been introduced at the University of Virginia. An essential feature of this course is its use of case studies. Four of the cases focus on design firms: IDEO, DEKA, Edison II, and William McDonough + partners. Students in the class conduct background research on these firms, their methods, cultures, and products; and come to class prepared to discuss what they have learned and debate key issues about the companies, their methods, tactics, and strategies, and their successes and failures. They must also learn about the key people in each company, and seek to understand their roles, personalities, and motivations. We also use cases that involve analyses of existing products and their redesign, intellectual property concerns, and issues of product liability.

A brief history of design thinking and its use in various disciplines and endeavors, will be presented; followed by a review of the use of cases in engineering education. We will present participants in this special session with two case studies - one of a product design firm, and the other the redesign of an existing product. Finally we will review the experiences of our students with using case studies, and their reactions to doing so.

In the age of the Internet, case studies can be significantly enriched by online resources [5, 12, 13]. Thus when we studied DEKA we had access to the company's website, many YouTube videos of Dean Kamen, and information on DEKA's products. The students are also expected to explore any books or articles they can find related to the particular company, its products, and the key people involved.

II. FOUR CASE STUDIES

IDEO is a product design firm in Palo Alto California started by Dave Kelley, a Stanford engineering professor. The firm was the subject of a Nightline television program and a popular book *The Art of Innovation* [6] written by Dave's brother, Tom. For this case study, we posted a series of questions to the students the night before the class and then called on selected students during the class. After the selected student gave an answer, other students could ask questions, challenge the answer, or elaborate with more information. This was the first case study of the semester and most students were not familiar with the case method. Some, of course, were more prepared than others but overall seem to benefit from and enjoy the experience. The students had a much deeper appreciation of the company, its culture, and the products they design than they would have gotten by listening to a lecture or merely reading a book.

Edison 2 won the Automotive X-prize with their very light car. This X-prize was given for a car capable of getting 100 miles to the gallon of gas (or its equivalent). The winning team was based in Charlottesville and Lynchburg, Virginia. Local real estate developer Oliver Kuttner was the visionary behind the very light car and he assembled a team of first-rate automotive engineers. Ron Mathis was his chief designer, and Brad Jaeger was chief mechanical engineer and a professional racecar driver. Jason Fagone's *Ingenious: A True Story of Invention, Automotive Daring, and the Race to Revive America* [4] follows the four unlikely teams that made it to the final competition.

The Edison 2 team provides a clear example of a group working from fundamental engineering principles and careful calculations in the design and testing of their vehicle. Their initial preconceptions were modified based on data and analysis. For example, their original vision was an electric car. However, Ron Mathis' calculations clearly showed that a gas powered vehicle could accomplish the goal, whereas electric vehicle could not. The weight of the batteries conflicted with the fundamental goal of producing the lightest possible car. Our students learn about how this team expanded its membership to acquire expertise and resources not available to the original group.

For the DEKA case study, each team focused on a particular product, chosen from Dean Kamen's early medical devices, iBOT, Segway, Slingshot, the Luke arm, and FIRST robotics. They discussed technical details of these products, their design features and commercial success (or lack thereof), and impact on individuals and society. We discussed the personal history of Dean Kamen and the evolution of DEKA. The students were able to trace how the various DEKA products related to each other and depended upon a core set of design elements.

William McDonough is an architect and former dean of the School of Architecture at the University of Virginia where he was known as the "Green Dean". He is the author of several books *The Hanover Principles* [9], *Cradle to Cradle*

[10] and *the Up-cycle* [11] and is a major leader in bringing sustainability to American business and manufacturing. Here the students traced McDonough's involvement with a variety of high profile architectural design projects around the world. They learned of his work with Michael Braungart, a chemist, on analyzing the toxic chemicals that go into many everyday consumer products. McDonough and Braungart developed a list of safe chemicals, then promoted their use in textiles, furniture design, and architectural applications.

We used McDonough's book *Cradle to Cradle* to understand his design philosophy and its implications for modern product design and manufacturing.

We are developing additional case studies around other engineers, architects, and designers, including Bert Rutan (Scaled Composites), and Sal Khan (the Khan Academy).

It is surprising how many engineering students don't know the names and accomplishments of modern engineers. When we asked him to name famous engineers they struggle to come up with names like Henry Ford, Thomas Edison, or Leonardo da Vinci. They are totally unaware of the accomplishments of many modern engineers and architects. These case studies are designed to show them what engineers do and how they work.

III. CASES AND THE CASE STUDY METHOD

Using whatever resources are available to them including books, articles, Internet searches, Ted talks, interviews and the webpages for their companies, students conduct deep research into each person and company. In the typical case study, any student can be called on at any time to answer the instructor's questions. These questions are usually not available in advance. We modified the standard case study method in two ways: for two of the cases, students worked in teams to conduct their research and prepare for the class, and we provided the questions in advance for some cases.

The goal of the case method is to promote critical thinking and decision making, rather than rote learning and memorization. The students also learn communication skills.

IV. AN ENTREPRENEURIAL CASE STUDY

We are also developing case studies based on the activities of several of our former students who have become successful entrepreneurs and product designers. One published case study involves Kaleo - a Richmond, Virginia company founded by Evan and Eric Edwards [8]. Evan is a mechanical engineer and Eric is a medical doctor. They developed a drug delivery system for epinephrine for severely allergic patients.

V. WHAT THE PARTICIPANTS WILL DO IN THIS SPECIAL SESSION

In the spirit of FIE, the special session will involve hands-on activities for the participants. We will provide a brief case study of a selected product design firm, and ask teams to analyze their decisions at key points in the evolution of the

firm. This case will present a subset of the material our students would use in an actual classroom environment.

We will also present a case involving an everyday consumer product and the kinds of issues users have with it. The participants will think of ways to improve the product and present a redesign based on their discussions.

These two examples will illustrate how the case study method can be used in engineering classes. Participants will be asked to reflect on how cases in the case study method can be used in their classes.

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