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Using Engineering Cases in Technology Education

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By Todd R. Kelley

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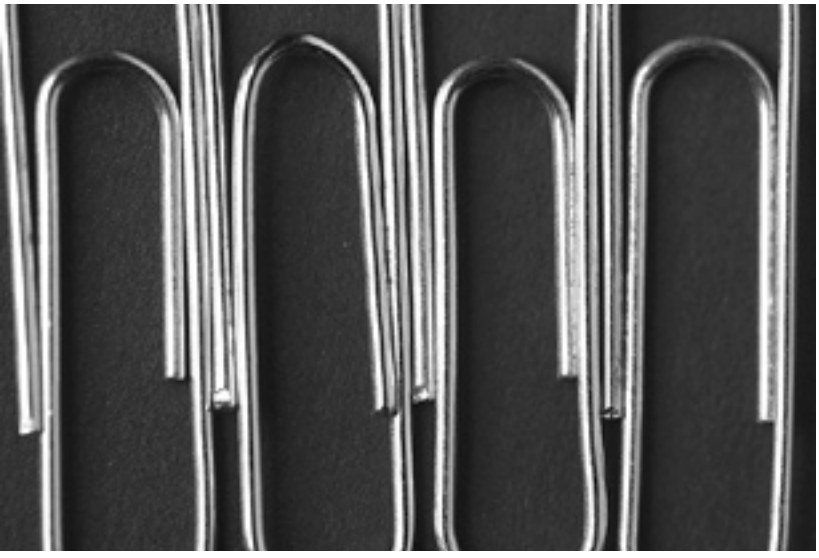

Henry Petroski (1996) documents a number of historical design cases that highlight the design evolution of everyday items such as the standard GEM paperclip.

Introduction

There has been a great deal of discussion in the past few years about implementing engineering design in K-12 classrooms. Experts from K-12 education, universities, industry, and government officials attended the ASEE leadership workshop on K-12 Engineering Outreach in June of 2004 and came to a consensus on the need to implement engineering in K-12 schools (Douglas, Iversen, & Kalyandurg, 2004). Many leaders in the field of technology education believe that developing technological literacy in students can be best delivered by teaching engineering design (Wicklein, 2006, Lewis, 2005, Dearing & Daugherty, 2004). The use of the engineering design process is stressed throughout *Standards for Technological Literacy: Content for the Study of Technology* (ITEA, 2000/2002/2007), especially Standards 8 through 13.

While there may be strong support for teaching engineering concepts to K-12 students, how this knowledge is properly delivered to high school students is still a debatable topic. This article seeks to consider engineering case studies as a logical way to teach the engineering design process to students not commonly familiar with it. Arguments have been made against assigning students to full-scale engineering design problems when they are new to engineering. Often novice engineering students lack the analytical tools necessary for successful development of design solutions to full-sale engineering problems (Petroski, 1998, Dym, 1994). Introducing engineering design to K-12 students through the employment of design case studies is a logical solution.

Design Case Studies Defined

Although design case studies have been used in engineering schools since the late 1960s, the term may be new to those in the field of technology education. Design case studies have a variety of definitions, depending on the source. The

general term *design case study* has several variations in title including *engineering cases* and *case studies*. Geza Kardos (1979) says that the terms "*engineer case*, *cases,* and *case studies* are used loosely and interchangeably," (p.1). In a separate article, Kardos (1979) defines engineering cases as " . . . a written account of an engineering activity as it was actually carried out" (p.1). H.O. Fuchs (1974) defines an engineering case as: "A case is a written account of an engineering job as it was actually done, or of an engineering problem as it was actually encountered" (p. 1). A common key to any engineering case is that the writing is based on factual information about a real engineering case or problem. One common practice is to change the names of the parties involved in the engineering case; however, the overall details must remain factual.

Variety of Formats

Some engineering cases tell the full story by providing the problem statement, the processes and procedures, and the actual applied solution; thus, these cases are known as *case histories*. "A case history is an account of an actual event or situation; it reviews the variables and circumstances, describes how a problem was solved, and examines consequences of decisions and the lessons learned" (Richards & Gorman, 2004, p. 2). Henry Petroski (1996) documents a number of historical design cases that highlight the design evolution of everyday items such as the standard GEM paperclip along with eight other design categories that are presented in the book *Invention by Design: How Engineers Get From Thought to Thing*. He provides an historical perspective of the design and engineering of everyday artifacts. Petroski provides early patents of many household items such as the zipper and aluminum can. Petroski also presents case histories that feature the detailed analysis of engineering, such as the case of a common pencil. This particular case history illustrates how important it is to scrutinize and interpret the often seemingly trivial details of engineering analysis. Some of Petroski's historical engineering design cases show the reader the details of how common household artifacts are mass-produced. Designing an artifact that meets a human need is one thing; designing it for mass production is another task entirely. Petroski provides some excellent historical cases that can provide students with greater insight into the world of design and engineering.

Case problems present an engineering case as an open-ended problem that can contain multiple solutions. The analysis and final solution stages to the engineering design process are intentionally left out of a case problem. A case problem can be an excellent way for students to study the engineering design process and provide an opportunity to determine on their own what aspects of the problem require analysis. A case problem then allows the students to make an informed decision about a proposed solution. The instructor can require students to defend their solutions by using the analysis data. This experience can provide new insight into how important it is for an engineer to carefully consider all aspects of a technical problem as well as increase the ability to defend the final solution based on factual information in a clear and logical manner.

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One very powerful format of engineering design cases is when cases are presented using *multimedia* formats. New engineering cases have been documented in multimedia forms including videotapes, CDs, and DVDs. This multimedia format allows engineering cases to include interviews with the stakeholders and principal engineers, visits to the site where the case takes place, and provides graphical and numeric data often obtained in the analysis stage of the engineering design process. Moreover, multimedia formats allow an instructor to hold a large amount of information about an engineering case in a compact form. The instructor has the ability in using multimedia formats to select only the information he or she wants students to use for their assignment. Multimedia formats can bring the engineering design case to life and allow for more individual interaction that might require students to locate the information they deem important

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to their assignment. Many public school systems today greatly limit or have eliminated field trips altogether, yet multimedia engineering cases provide a real-world virtual field trip inside the world of engineering that might otherwise have been out of reach (Richards & Gorman, 2004). A program in conjunction with Tuskegee University effectively uses multimedia-formatted engineering design cases in K-12 schools. The results of the program indicated that using these cases broadened students' understanding of engineering, and it boosted students' retention rates (Seif, 1994).

Why Engineering Cases for Technology Education?

Much of the writing about the application of case studies in engineering education suggests that engineering cases are an excellent learning tool to use with students inexperienced with an engineering design process—a freshman engineering major or nonengineering major, for example, because he or she would not possess the analytical tools to properly engage in full-scale engineering design experiences (Petroski, 1998). Petroski suggests that case studies enable students to understand engineering in the broad context in which engineering is actually practiced. One of the greatest benefits of using engineering cases to teach engineering design to a novice is that there are no prerequisites in the study of an engineering case study; generally, anyone can learn about engineering through engineering cases.

Case Studies Teach About Real-World Engineering

Most case studies are generated from real-world situations; consequently, they contain many more unknowns than problems developed for a textbook example. It is very important that students learn that engineering is all about working with unknowns. Real case studies illustrate to students that even though a solution is generated, such as the GEM paper clip, it does not mean that the solution is without problems. Engineering is about compromise—an important reality of engineering that technology education students must learn. Technology education students will likely learn more from the flaws and failures of the featured engineering solutions in an engineering case study than about the successes of a design solution. Often individuals learn as much from failures as they do from successes. Some engineering cases specifically select failures in engineering to highlight such real cases as the Tacoma Narrows Bridge, Failure of a Large Gearset, and Twelve Years to Discover the Obvious (Henderson, Bellman, & Furman, 1983). Students provided with an opportunity to study these cases can formulate their own judgments and decisions about such cases and compare their conclusions with those of the real engineers assigned to the actual cases. Technology education students studying case studies will be given an opportunity to view the overall process of engineering design through a real engineering example allowing students to have a better understanding of the caliber of the problems that engineers encounter, as well the processes and procedures engineers apply to solve such problems.

Students Benefit from Engineering Cases

Effective engineering cases present the complete details of an engineering problem as well as the entire process undertaken by the principal engineer to solve such a problem. Consequently, an engineering case is drastically different from a problem that might be presented in an engineering textbook. An engineering case presents more than a simple mathematical problem. Engineering students who only practice engineering problems often have a false sense of security that engineering problems are crisp and narrow analytical problems. Real engineering problems are ill-defined and are embedded within an entire system; therefore, analysis must consider the entire system. Engineering cases also require students to go beyond a single answer. Because a real case study is multifaceted, it requires students to think about all aspects of the engineering design process, not just an analytical piece (Henderson, Bellman, & Furman, 1983). Engineering cases allow students to learn how to sift through the details of an

engineering case to discover the most essential information needed to address the critical issues; this is known to the engineering community as framing or setting the problem. When students are asked to place judgments on the approaches and procedures of a practicing engineer, their learning moves from low-level knowledge and application to higher levels of learning such as synthesis and evaluation.

Engineering Cases Motivate

Many in the engineering community have suggested using engineering cases to motivate engineering students and to address the problems of retention (Smith & Kardos, 1987). Engineering design cases provide students with meaningful, real-world examples of applying math and science to engineering problems. H.O. Fuchs (1974) believes that engineering cases motivate students because a well-written case study draws on their interests and engages them in the engineering problem. He believes that students are able to get into the case study because cases include the human or social factors of an engineering problem. Engineering cases are about real people with real problems, an important element in order for students to have the ability to identify with the problem (Fuchs, 1974). Students can approach an engineering case as if they are the project engineer, thus providing a sense of ownership that is not easily achieved with a standard textbook engineering problem. Some engineering cases are written excluding actual applied solutions, allowing students to apply their own knowledge and frame the problem to solve in the way they dictate. This provides motivation and opportunity for creativity. Engineering cases provide the important lesson that engineering problems do not contain a single correct answer. This fact can empower a student to develop his or her own approach to the problem.

Design case studies have been successfully used in K-12 programs to increase technical awareness and to attract students into the field of engineering. Tuskegee University has successfully worked with three public school corporations to develop K-12 engineering education programs that utilize engineering design cases, and students' perceptions of engineering through the use of engineering cases have been favorable as indicated by program surveys (Seif, 1994).

Engineering Case Libraries

The Engineering Case Program originated at Stanford University in 1964 and is still sponsored by the American Society for Engineering Education (ASEE). An ASEE Case Study Committee exists under the Design in Engineering Education Division (DEED) of ASEE. The Rose-Hulman Institute of Technology houses the Engineering Case Library. Rose-Hulman is responsible for reproducing and distributing the over 250 design cases housed at the library. Another source for engineering cases is the National Engineering Education Delivery System (NEEDS). This source for engineering cases has been developed by the National Science Foundation Synthesis Coalition (Richards & Gorman, 2004).

Conclusion

Engineering case studies have been used successfully as teaching tools by the engineering education community for many years, and the benefits of using engineering cases to teach the engineering design process is widely documented. However, many educators in the field of technology education may not be familiar with engineering cases and the potential they possess as teaching tools. Certainly, some modification and editing of an engineering case must take place to adjust the content so that it can be appropriately used with K-12 students, but engineering cases can provide the needed details about engineering that might otherwise be missed without their use. Engineering cases are another tool that has potential to assist K-12 educators to properly implement engineering concepts into the curriculum.

References

Dearing, B. M. & Daugherty, M. K. (2004). Delivering engineering content in technology education. *The Technology Teacher, 64* (3), 8-11.

Douglas, J., Iversen, E., & Kalyandurg, C. (2004). *Engineering in the K-12 classroom: An analysis of current practices and guidelines for the future.* A production of the ASEE Engineering K12 Center.

Dym, Clive L. (1994). Teaching design to freshmen: Style and content. *Journal of Engineering Education*, *83* (4), 303-310.

Fuchs, H. O. (1974). On kindling flames with cases. *Engineering Education*, (March issue).

Henderson, J. M., Bellman, L. G., & Furman, B. J. (1983, January). A Case for teaching engineering with cases, *Engineering Education*, pp. 288-292.

ITEA. (2000/2002/2007). *Standards for technological literacy: Content for the study of technology*. Reston, VA: Author.

Kardos, G. (1979, March). *On writing engineering cases.* Paper presented at ASEE National Conference on Engineering Case Studies.

Kardos, G. (1979, March). *Engineering cases in the classroom.* Paper presented at the ASEE National Conference on Engineering Case Studies.

Lewis, T. (2005). Coming to terms with engineering design as content. *Journal of Technology Education*, *16* (2), 37-54.

Petroski, H. (1998, October). Polishing the GEM: A first-year design project. *Journal of Engineering Education*, pp. 313-324.

Petroski, H. (1996). *Invention by design: How engineers get from thought to thing*. Cambridge: Harvard University Press.

Richards, L. G. & Gorman, M. E. (2004, June). *Using case studies to teach engineering design and ethics*. Paper presented at the American Society for Engineering Education Annual Conference & Exposition, Salt Lake City, UT.

Seif, M. (1994, March). *Multimedia design case studies*. Paper presented at ASEE/GSW, Southern University, Baton. Rouge, LA.

Smith, C. O. & Kardos, G. (1987, January). Need design content for accreditation? Try engineering cases! *Engineering Education*, pp. 228-230.

Wicklein, R. C. (2006). Five good reasons for engineering design as a focus for technology education. *The Technology Teacher, 65*(7), 25-29.

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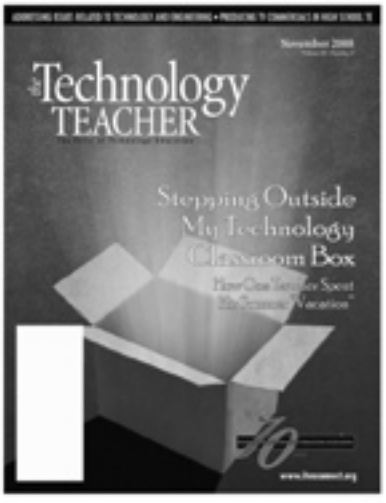

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