Research Brief
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Identifying and Investigating Difficult Concepts in Engineering Mechanics and Electric Circuits

Authors: Ruth Streveler, Monica Geist, Ravel Ammerman, Candace Sulzbach, Ronald Miller, Barbara Olds, and Mary Nelson
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This study extends ongoing work to identify difficult concepts in thermal and transport science and measure students' understanding of those concepts via a concept inventory. Two research questions motivated this study: "What important concepts in electric circuits and engineering mechanics do students find difficult to learn?" and "How can we describe students' mental models of the concepts identified in the previous question?" This study was designed with the hope that commonalities might be found among difficult concepts in chemical engineering, mechanical engineering, and electrical engineering.

Implications of Findings

Interviewees used language suggesting they viewed fundamental concepts like "force" and "voltage" as *substances* when in fact they are *processes* or *interactions*.

The results of this study agree with previous studies of engineering difficult concepts and misconceptions that suggest that engineering students who are academically successful often lack deep understanding of fundamental concepts in their field (e.g., see Reiner et al., Cognition and Instruction, 18(1):1-43, 2000). Taken together, these studies suggest that evidence of substance-based models for processes may be present among students from chemical, mechanical and electrical engineering. If true, this suggests that helping students to create more accurate mental models that represent emergent processes truly as processes, not substances, may be beneficial in many areas of engineering.

Method and Background

This research was conducted in two parts. The team first determined what concepts are difficult as judged by engineering faculty and content experts and second, focused on measuring students' understanding of these difficult concepts.

In the first step, a Delphi methodology was used to determine which concepts in electrical circuits and in engineering mechanics were important, and yet difficult to learn. The Delphi method elicits and refines ideas about difficult concepts from a panel of engineering faculty experts. The method draws upon the experts' knowledge and collective opinion through a series of questionnaires interspersed with controlled opinion feedback. (See references in the full text article in the link below for a more complete explanation of this methodology.)

In the next part of the experiment, the team gathered data about the degree of understanding of these concepts by seniors in Mechanical/Civil and Electrical Engineering. The "substance-based-schema" work of Reiner et al. was used to inform the problem of identifying the students' mental models of these “difficult concepts.” Reiner et al. posited that fundamental concepts like *force*, *voltage*, and *current* may be difficult for students to learn because students view those processes as if they were substances. Seniors at Colorado School of Mines with a specialty in either electrical, civil, or mechanical engineering were recruited in two rounds via an e-mail to the engineering seniors e-mail list. Following the first round of interviews, content experts could make changes to the list of interview questions for the second round of interviews.

What We Found

Data from the Delphi survey indicated a convergence of opinions. Although the results of the Delphi did converge as expected, neither the Electric Circuits and Engineering Mechanics Delphis indicated a group of concepts that were rated both as very important <u>and</u> very difficult to learn (i.e., poorly understood), creating some ambiguity about which concepts warranted further investigation.

In order to gather additional input from experts, the results of the Delphi surveys were taken to an interactive workshop hosted at the 2004 Frontiers in Education Conference. Workshop participants were invited to gather according to discipline (chemical, mechanical, or electrical engineering) and then examine and comment on the Delphi results that most closely matched their expertise. Content experts were also consulted and met with the research team to determine which concepts in each field should be investigated, and a cognitive psychologist offered theoretical "concepts of interest." It was determined that the Engineering Mechanics interviews should focus on *force*; *stress* and *strain*; *friction*; and *moment of inertia*. Electric Circuits interviews would focus on *AC steady-state circuit analysis*; the *five fundamental electrical quantities* (charge, current, voltage, power, and energy); *Kirchoff's Laws*; and *Thevenin/Norton* equivalent circuits. Using these lists as guides, content experts created both calculation-based and open-ended questions.

Data from the interviews designed to describe students’ mental models of the concepts listed above was gathered in two stages (described above). Results suggest that concepts rated as important and well-understood by the Delphi participants are NOT understood by students. It is possible the students who were interviewed were not representative of the general population. Interviewees were self-selected, there was no grade point requirement, and all came from the same institution. They also volunteered knowing they would be asked to explain difficult concepts, possibly skewing participants toward those who felt they understood the concepts <u>well</u>.

Analysis of the data indicated that these students do not fully understand many fundamental concepts. Interviewees used language suggesting they viewed fundamental concepts like "force" and "voltage" as *substances* when in fact they are *processes* or *interactions*.

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