The Process of Engineering Design: A Comparison of Three Representations

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The Center for Engineering Learning & Teaching (CELT) was established in 1998 in the College of Engineering at the University of Washington. We are the first center in the nation in a College of Engineering to combine a research and instructional development mission. Over the past decade, we have been conducting in depth research on understanding how engineering education and years of experience shape individuals' engineering design processes.

Studies of the Engineering Design Process

Method

Participants: Data were collected from 32 freshmen, 32 senior engineering students, and 19 practicing engineers (experts).

Experiment: Participants were given 3 hours to design a community playground (working individually in a lab setting) and asked to think aloud. These sessions were audio recorded.

Analyses

Coding: To understand the design process, we synthesized a prescriptive model of how design is accomplished from several engineering design texts, as detailed in the table below. The design activity definitions were used to code the transcripts of the verbal protocol data. Researchers also conducted a separate quality scoring of each participant's final playground design.

Design Stages	Activities Involved
Problem Scoping (PS)	Problem Definition (PD), Gathering Information (GATH)
Designing Alternative Solutions (DAS)	Generating Ideas (GEN), Modeling (MOD), Feasibility Analysis (FEAS), Evaluation (EVAL)
Project Realization (PR)	Decision (DEC), Communication (COM)

Selected findings

Compared to freshmen, seniors have higher quality designs and scope the problem more effectively by considering more categories of information. Seniors also make more transitions among design steps and progress further in the design process.

Compared to students, expert s spend more time in all design stages and gather more information (explicitly) that covers more information categories. Experts also tend to exhibit a "cascade" pattern of transitions.

Graphical Representations

We have developed and refined three methods for graphically representing the design process over time. These representations utilize the same timestamped, segmented transcripts as data.

Process Timelines

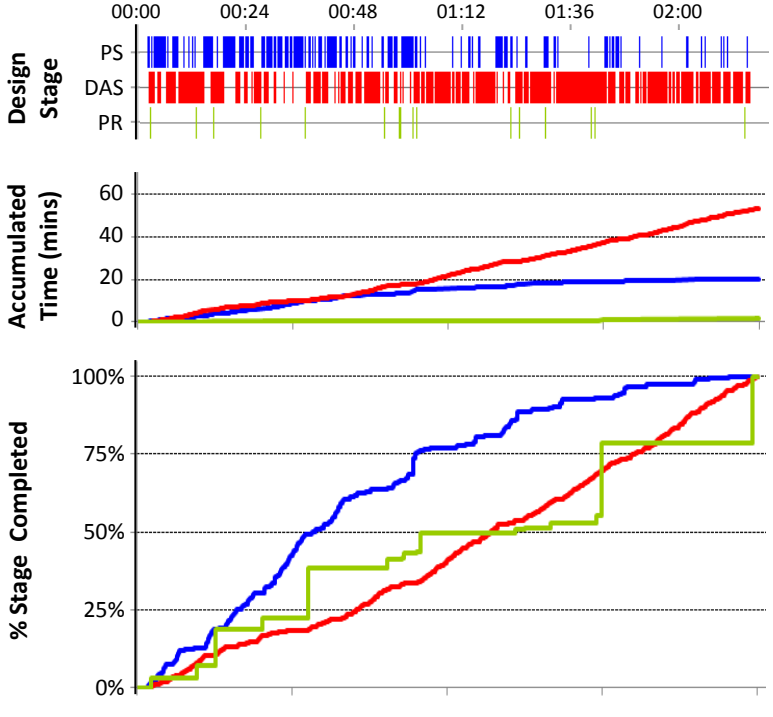
For each design stage / activity, a separate timeline indicates when and for how long the participant engaged in that stage / activity during the overall design session.

Cumulative Time Plot

A running total of the time spent in each stage / activity is plotted across the overall design session. Provides for clear quantitative comparisons between the different stages / activities.

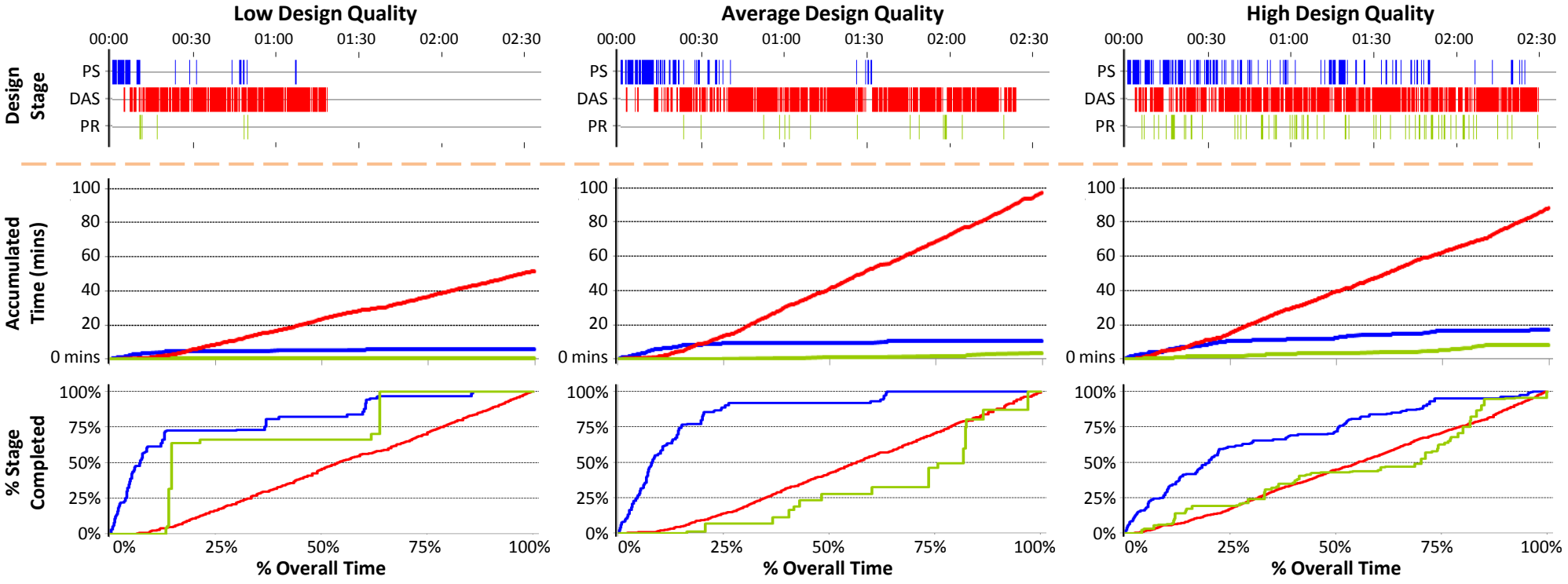
Progress Time Plot

Separate curves for each stage / activity indicate fraction of total time eventually spent in that stage / activity. Makes clear the shifting emphases the participant places on stages / activities throughout the design session.

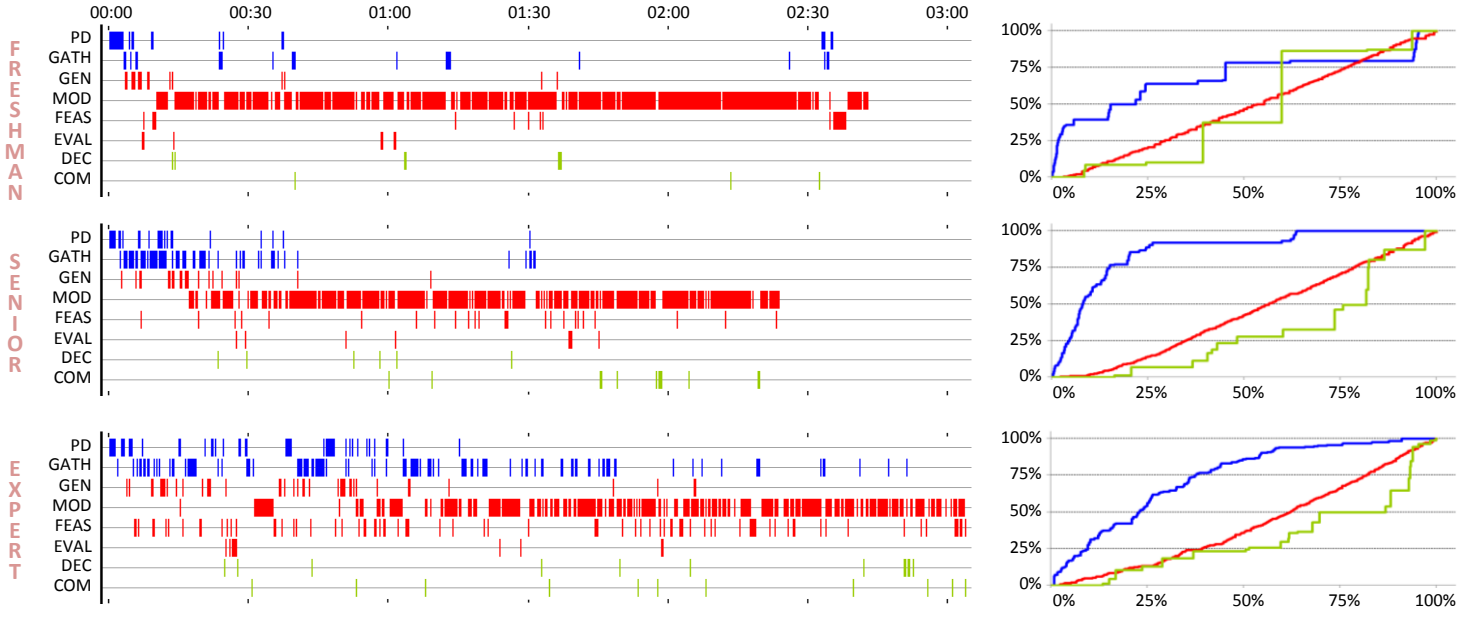


Design stage process timeline (top), cumulative time plot, and progress time plot for a freshman engineering student with a high quality playground design. Time is represented from left to right.

Comparing Senior Engineering Students with Differing Quality of Designs



Comparing Average Quality Designs by Engineers of Differing Levels of Experience



References

Atman, C.J., Chimka, J.R., Bursic, K.M., and Nachtmann, H.L. A comparison of freshman and senior engineering design processes. *Design Studies,* 1999, 20(2), 131-152.

Atman, C.J., Cardella, M.E., Turns, J., and Adams, R. Comparing freshman and senior engineering design processes: An in-depth follow-up study. *Design Studies*, 2005, 26(4), 325-357.

Atman, C.J., Adams, R., Mosborg S., Cardella, M., Turns, J., and Saleem, J. Engineering design processes: A comparison of students and expert practitioners. *J. of Eng. Educ.,* 2007, 96(4), 359-379.

Atman, C.J., Deibel, K., and Borgford-Parnell, J. The process of engineering design: A comparison of three representations. *Proceedings of the I. Conference on Eng. Design*, 2009.

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