Designing Design Learning:
Seeing, Hearing, and Representing

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Collaborators on the work featured in this presentation: Clarence Acox, Robin Adams, Jim Borgford-Parnell, Karen Bursic, Monica Cardella, Justin Chimka, Kate Deibel, Zach Goist, Brian Hayes, Bob Knatt, Janet McDonnell, Annegrete Mølhave, Susan Mosborg, Heather Nachtmann, Will Richey, Jason Saleem, Jennifer Turns, Cheryl Wang, and Ken Yasuhara

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Collaborators on design process research

- Collaborators, co-authors, and research team members include Robin Adams, Brad Arneson, Theresa Barker, Emma Bulojewski, Mary Besterfield-Sacre, Jim Blair, Carie Bodle, Laura Bogusch, Jim Borgford-Parnell, Karen Bursic, Ryan Campbell, Monica Cardella, Soomin Chang, Justin Chimka, Kate Deibel, Zach Goist, Brian Hayes, Melissa Jones, Allison Kang, Deborah Kilgore, Kristina Krause, Vipin Kumar, Alex Lew, Stefanie Lozito, Janet McDonnell, Annegrete Mølhave, Andrew Morozov, Susan Mosborg, Carie Mullins, Heather Nachtmann, Wai Ho Ng, Will Richey, Eddie Rhone, Axel Roesler, Jason Saleem, Elvia Sierra-Badillo, Roy Sunarso, Steve Tanimoto, Jennifer Turns, Cheryl Wang, Ken Yasuhara, and Mark Zachry…
- …and over 75 additional undergraduate students

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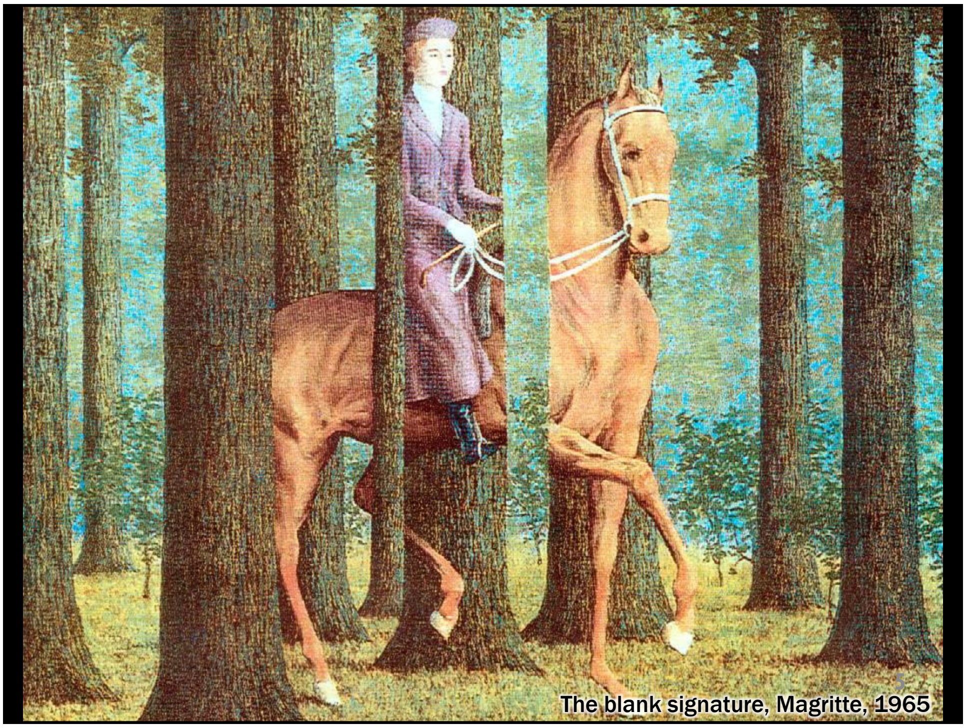
Defining engineering (Bill Wulf)

- Engineering is "design under constraint."
- Engineering is…
  - Creating
  - Designing what can be
  - Constrained by…
    - Nature
    - Cost
    - Concerns of safety
    - Reliability
    - Environmental impact
    - Manufacturability
    - Maintainability
    - Many other such "-ilities"

(Wulf, 1998)

Seeing, hearing, and representing design



The blank signature, Magritte, 1965

Making sense of engineering design

- Seeing design
- Hearing design
- Representing design

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Studying design expertise

- Method: verbal protocol analysis
  - Individuals in a lab setting
  - 3 hours to design a community playground
  - Think-aloud protocol and audio recording
  - Segmentation and coding of transcript data
  - Inter-coder reliability and arbitration
- Participants
  - First-year engineering students (n = 26)
  - Graduating senior engineering students (n = 24)
  - Practicing engineering experts (n = 19)

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Problem statement: Design a playground

- You live in a mid-size city. A local resident has recently donated a corner lot for a playground. Since you are an engineer who lives in the neighborhood, you have been asked by the city to design a playground.
- You estimate that most of the children who will use the playground will range from 1 to 10 years of age. Twelve children should be kept busy at any one time. There should be at least three different types of activities for the children. Any equipment you design must be safe for the children, remain outside all year long, not cost too much, and comply with the Americans with Disabilities Act.
- The neighborhood does not have the time or money to buy ready made pieces of equipment. Your design should use materials that are available at any hardware or lumber store. The playground must be ready for use in 2 months.

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Why a playground?

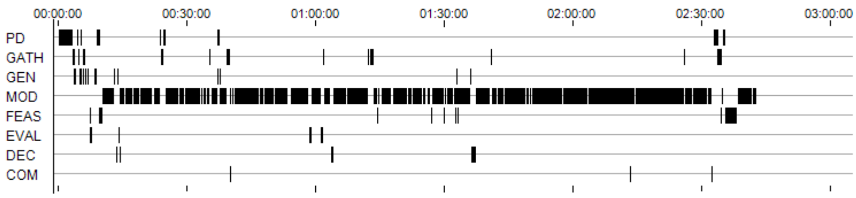
Defining design: Design process activities

Derived from analysis of 7 engineering texts

Design Activities	Design Stages
(Identification of a Need) Problem Definition Information Gathering	Problem Scoping
Generation of Ideas Modeling Feasibility of analysis Evaluation	Developing Alternative Solutions
Decision Communication (Implementation)	Project Realization

A design process timeline

First-Year (Quality Score = 0.45)



PD: Problem Definition
GATH: Gathering Information
GEN: Generating Ideas
MOD: Modeling

FEAS: Feasibility Analysis
EVAL: Evaluation
DEC: Decision Making
COM: Communication

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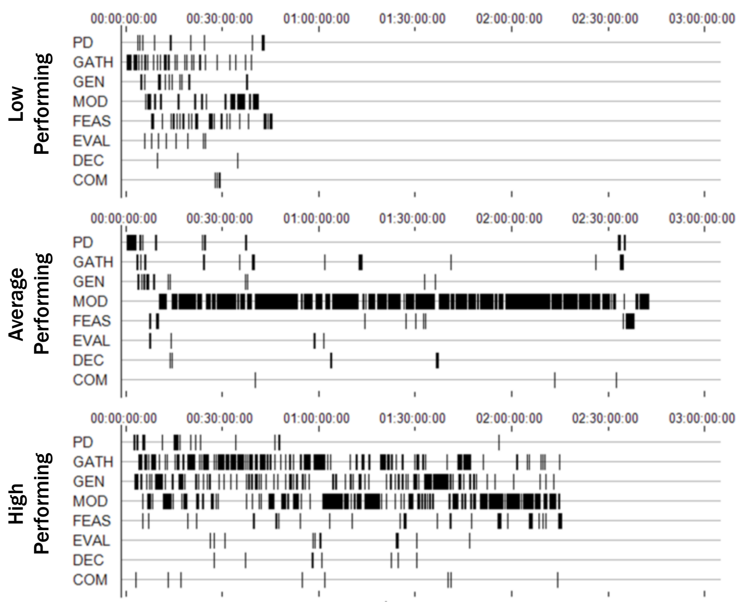
First-Year engineering students



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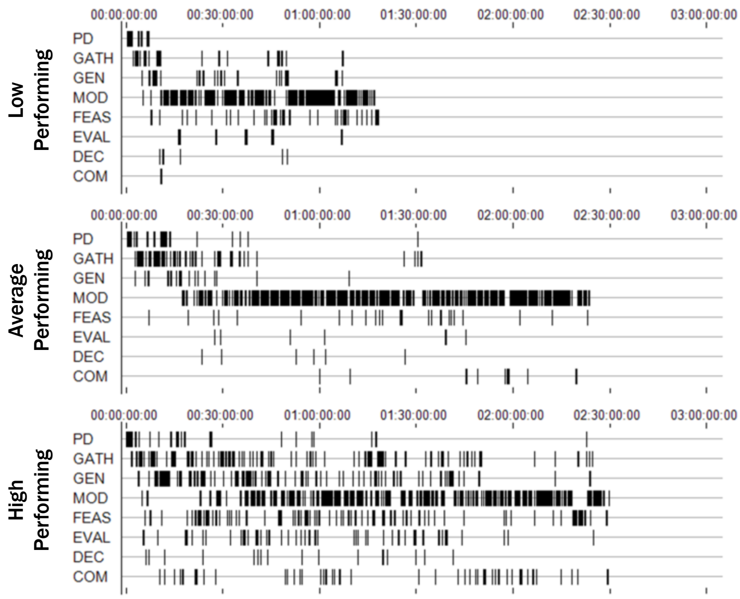
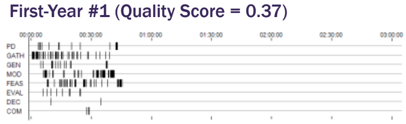
Graduating engineering students

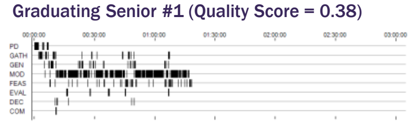


Learning activity: What do you see?

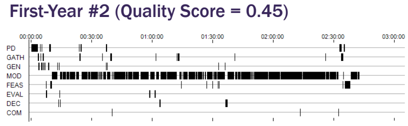
First-Year #1 (Quality Score = 0.37)



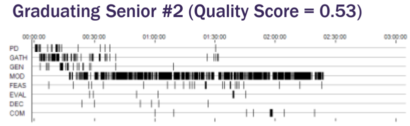
Graduating Senior #1 (Quality Score = 0.38)



First-Year #2 (Quality Score = 0.45)

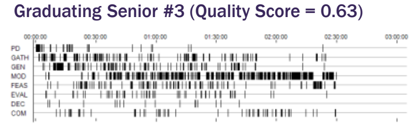


Graduating Senior #2 (Quality Score = 0.53)



First-Year #3 (Quality Score = 0.62)

Graduating Senior #3 (Quality Score = 0.63)



What similarities and differences do you see between the first-year and graduating senior engineering students?

Do these similarities also involve the quality scores?

Selected student insights

- "The highest quality scores in both groups use a greater range of activities, instead of just modeling."
- "Problem definition is key to the overall project. Remind yourself of what you are doing and what is really being asked. Pick your head up from the paper (modeling!) and analyze the problem."
- "Success is strongly correlated with gathering data and defining the problem early on."

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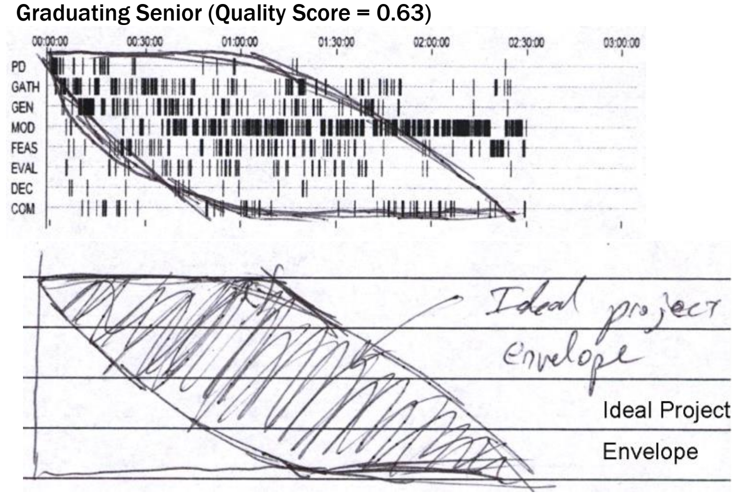
Selected student insights

Graduating Senior (Quality Score = 0.63)



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Design research: Findings

- Compared to first-year students, *graduating seniors*…
  - have higher-quality designs.
  - scope the problem more effectively by considering more categories of information.
  - make more transitions among design steps.
  - progress farther in the design process.
- (These differences are statistically significant.)

(Atman, Chimka, Bursic, & Nachtmann, 1999)

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Student feedback about the exercise

- "Next year, having this lecture in the first or second week would be even better."

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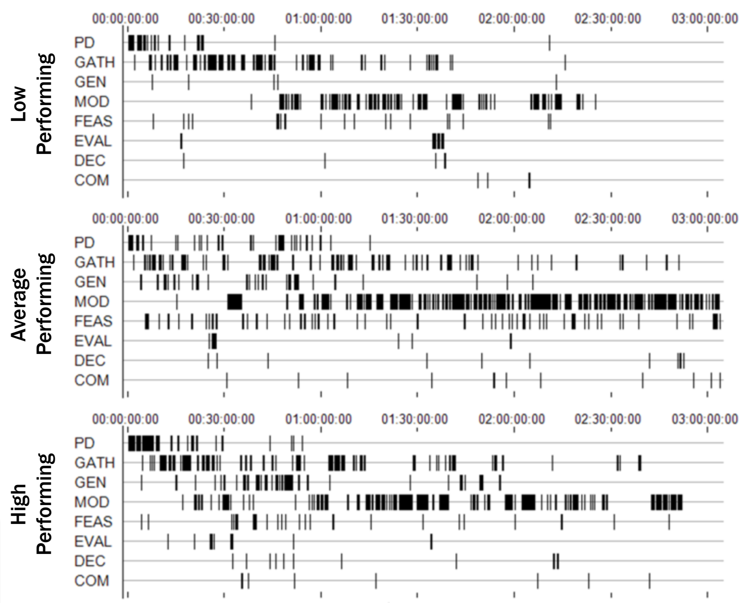
Design research: Findings

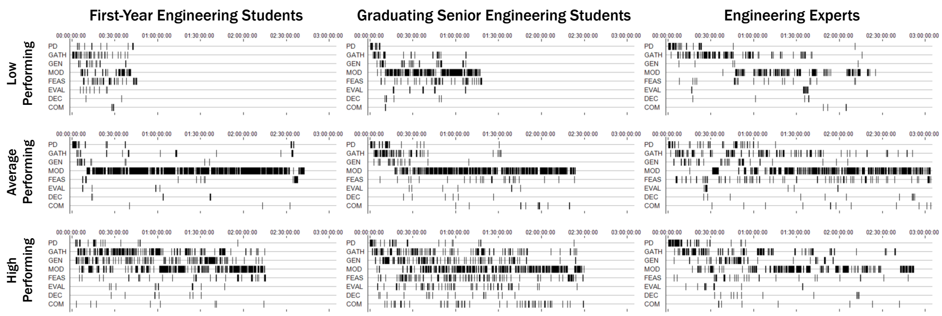
- Compared to students, *experts*…
  - spend more time solving the problems in all design stages.
  - consider more objects in their design process.
  - scope the problem more effectively by gathering more information (explicitly) and covering more categories.
  - exhibit a "cascade" pattern of transitions.
- (These differences are statistically significant.)

(Atman, Adams, Cardella, Turns, Mosborg, & Saleem, 2007)

Engineering experts



"Squint" analysis



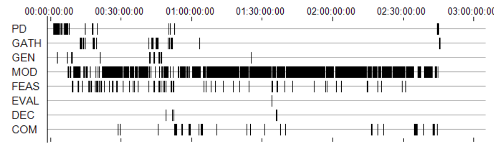
What about other populations, problems, etc.?

- Consistent patterns found with
  - Other populations
    - Undergraduate engineering students
    - Engineering faculty
    - Domain experts
  - Other design problems
  - Other research methods
  - Design teams
- Design and iteration, mathematics, context/ gathering information, reflection…

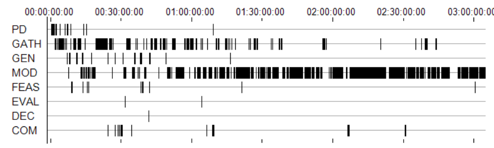
Individuals, Design a playground

- Undergraduate engineering students from a different institution
  - First-years (n = 6)
  - Graduating seniors (n = 8)

First-Year



Graduating Senior

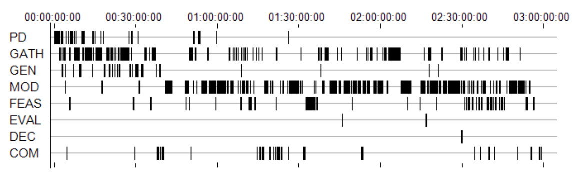


(Deibel, Atman, Saleem, Kang, & Ng, 2007)

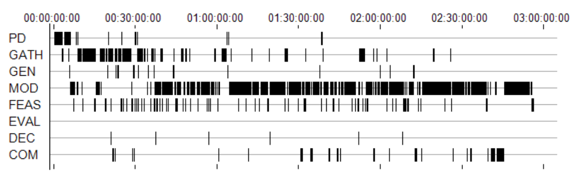
Individuals, Design a playground

- Engineering faculty (n = 4)
- Playground-design domain experts (n = 4)

Engineering faculty



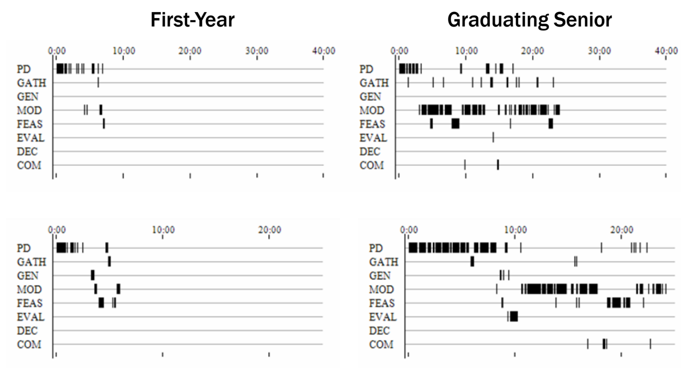
Domain expert



(Atman, Turns, Cardella, & Adams, 2003; Krause, Atman, Borgford-Parnell, & Yasuhara, 2013)

Individuals, Within-subject longitudinal

- First-years (n = 32), graduating seniors (n = 61); 18 within-subject
- Design a Ping-pong Ball Launcher
- Design a Street Crossing System



(Cardella, Atman, Turns, & Adams, 2008)

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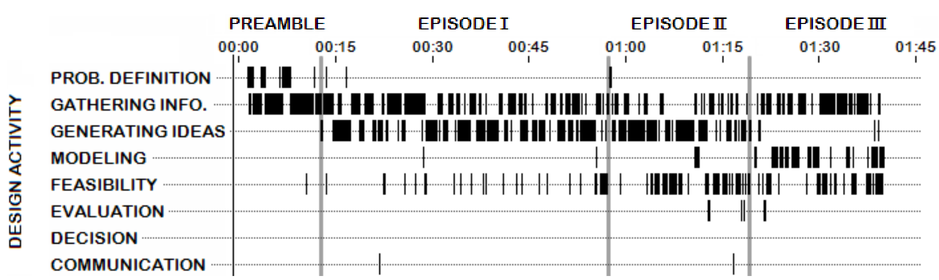
Team, Design a digital pen

- One team of 7 members



(Atman, Borgford-Parnell, Deibel, Kang, Ng, Kilgore, & Turns, 2009)

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Design and…

- Iteration
  - Adams' dissertation on iterative design behavior (2001)
  - Adams' Design Research Society paper (2002)
- Mathematics
  - Cardella's dissertation (2006)
  - Cardella & Atman's ASEE paper (2007)
- Context/gathering information
  - CAEE final report (Atman, Sheppard, et al., 2010)
  - Kilgore, Atman, Yasuhara, Barker, & Morozov in *JEE* (2007)
  - Bursic & Atman in *Quality Management Journal* (1997)
- Reflection
  - Adams, Turns, & Atman in *Design Studies* (2003)
  - Krause, Huneke, Yasuhara, & Atman at IPCC (2013)

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Making sense of engineering design

- Seeing design
- **Hearing design**
- Representing design

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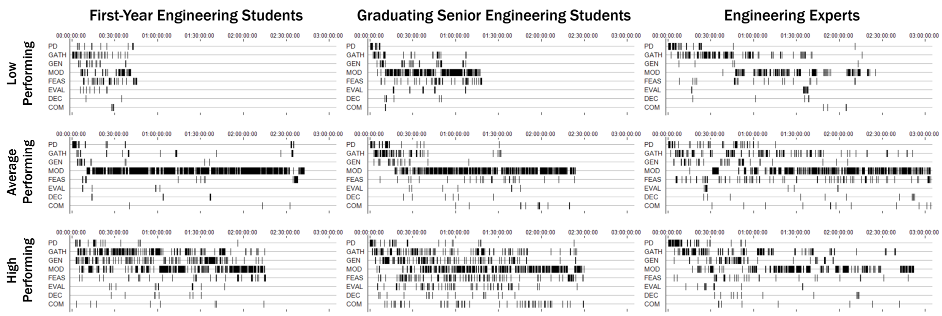
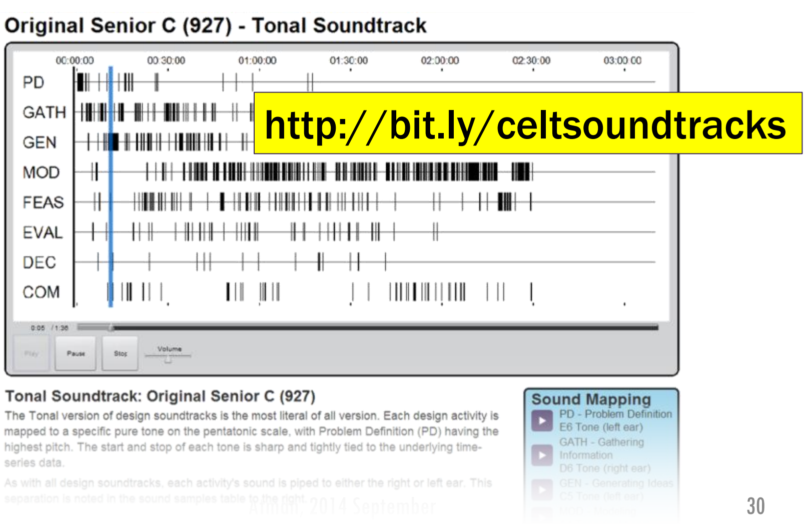
What does design sound like?



Design soundtracks



Making sense of engineering design

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Design teacher perspectives

- “If you hear monotone, it’s not like you’re doing a high-performance task.” (Mechanical Engr.)
- “There is a story here…[timelines are] a great tool for making students more aware of the process [and] how it can unfold.” (Product Designer)
- “I would use the timelines to emphasize and reinforce the difficulty/training/complexity it takes to create something elegantly simple.” (Sound Artist)

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Jazz teacher perspectives

Clarence Acox

Bob Knatt

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Jazz perspectives

- "Generating ideas…from the jazz process, that automatically comes from the creative aspect of improvisation." (Acox)
- "If you wanted to use all these [three freshman timelines], it would be a full jazz band." (Acox)
- Knatt saw the timelines as representing the collaborative process that Dizzy Gillespie and Charlie Parker engaged in while composing Anthropology, "one of the most exciting and legendary charts."

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Industry perspectives

- Make personal representation for students.
  - Have students describe their process and link it to real-life experiences.
  - Pair students with expert mentors and discuss different processes.
  - Students see what to improve. Help them take negative feedback.
  - Emphasize reflection.
- Compare Agile vs. Waterfall project management approaches in the workplace.
- Represent historical analyses of product development (iPad, Model T).
- Hiring task

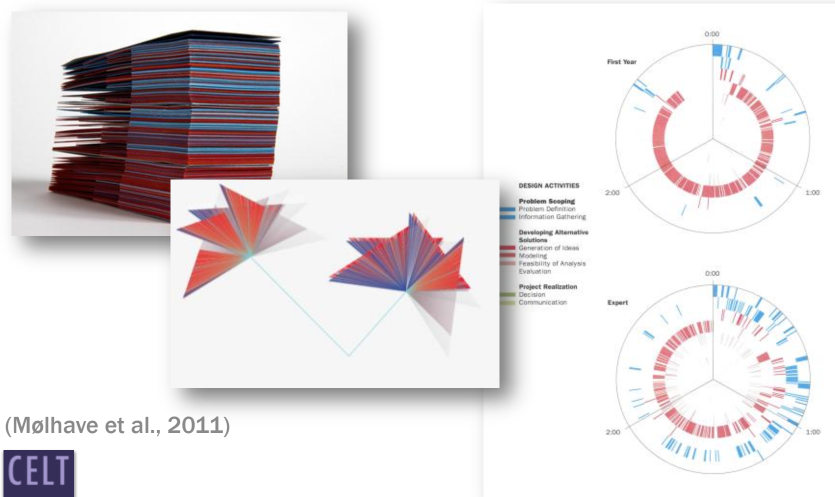
(UW HCDE Corporate Advisory Board members, personal communication, 2012)

Learning activity: Representing design

- Pair of activities developed by McDonnell and Mølhave at Central Saint Martins College of Arts and Design, London
  1. Design timelines and coded transcripts as basis for students creating new representations
  2. Student observations of own design process as basis for creating new representations

(Mølhave, McDonnell, & Atman, 2011)

Design timelines and coded data as basis for new representations (CSM)



(Mølhave et al., 2011)

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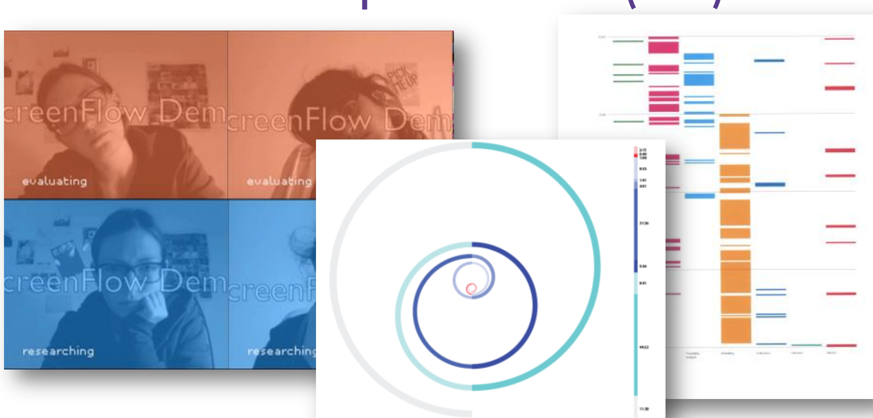
Student observation of own design process as basis for new representations (CSM)



(Mølhave et al., 2011)

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Learning activity: Design timelines as "advance organizers"

- Research group in Human Centered Design & Engineering at UW
- Build on Central Saint Martins activities
- Additional activities
  - Study design models, broadly defined
  - Define context
  - Understand perspective
  - Create "design memory-aid, ear-worm, or mantra"
- Implemented in winter and fall, 2013 (Atman)

(Atman, Hayes, Richey, Wang, & Campbell, 2013)

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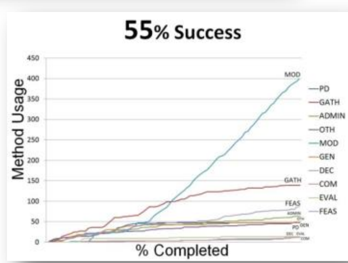
Design timelines and coded data as basis for new representations (UW)



(Atman et al., 2013)

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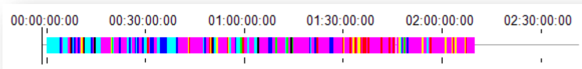
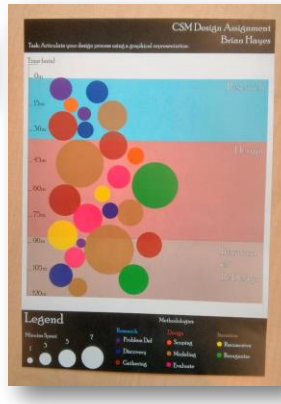
Student observation of own design process as basis for new representations (UW)





(Atman et al., 2013)

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Design memory-aid/ear-worm/mantra (UW)

The harder I work,
the luckier I get.

(Atman et al., 2013)

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Making sense of engineering design

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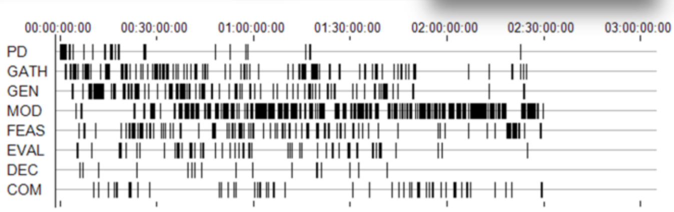
- Hearing design
- Representing design

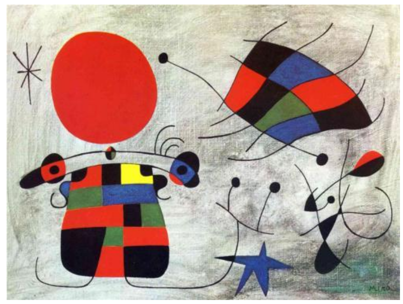
Seeing, hearing, and representing design



What's next? Some insight from Joan Miró

"Two and two do not make four. Only accountants think that. But that is not enough: a painting must make that clear; it must fertilize the imagination.

—Miró, 1959



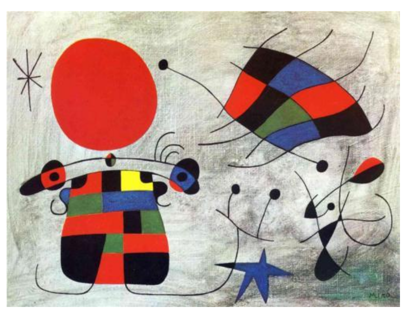
The Smile of the Flamboyant Wings, Miró, 1953

What's next? Some insight from Joan Miró

"Two and two do not make four. Only accountants think that. But that is not enough: a painting must make that clear; it must fertilize the imagination.

I do not exclude the possibility that when looking at one of my paintings, a businessman might discover a way to do business, or a scholar might find the answer to a problem."

—Miró, 1959



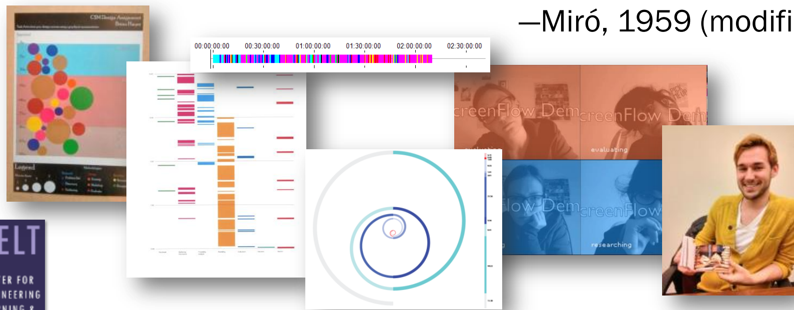
The Smile of the Flamboyant Wings, Miró, 1953

What's next? Seeing, hearing, and representing design

Two and two do not make four. Only accountants think that. But that is not enough: a **[design process representation]** must make that clear; it must fertilize the imagination.

I do not exclude the possibility that when looking at **[their own design process, an engineer]** might discover a way to do **[engineering]**, or a scholar might find the answer to a problem.

—Miró, 1959 (modified)



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What's next?

- Seeing, hearing, and representing design
  - Early indications show success.
  - Deeper investigation underway (with McDonnell)
  - Please contact us if you are interested using these tasks.
  - Design tasks will be available on the CELT web site.

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What's next?

- Reflection and design
  - Consortium to Promote Reflection in Engineering Education (CPREE)
  - 12 institutions in the U.S.
  - Funded by the Leona M. and Harry B. Helmsley Charitable Trust
  - Turns, Borgford-Parnell, Yasuhara, & Lund
  - http://bit.ly/cpreeweb
  - http://cpree.uw.edu

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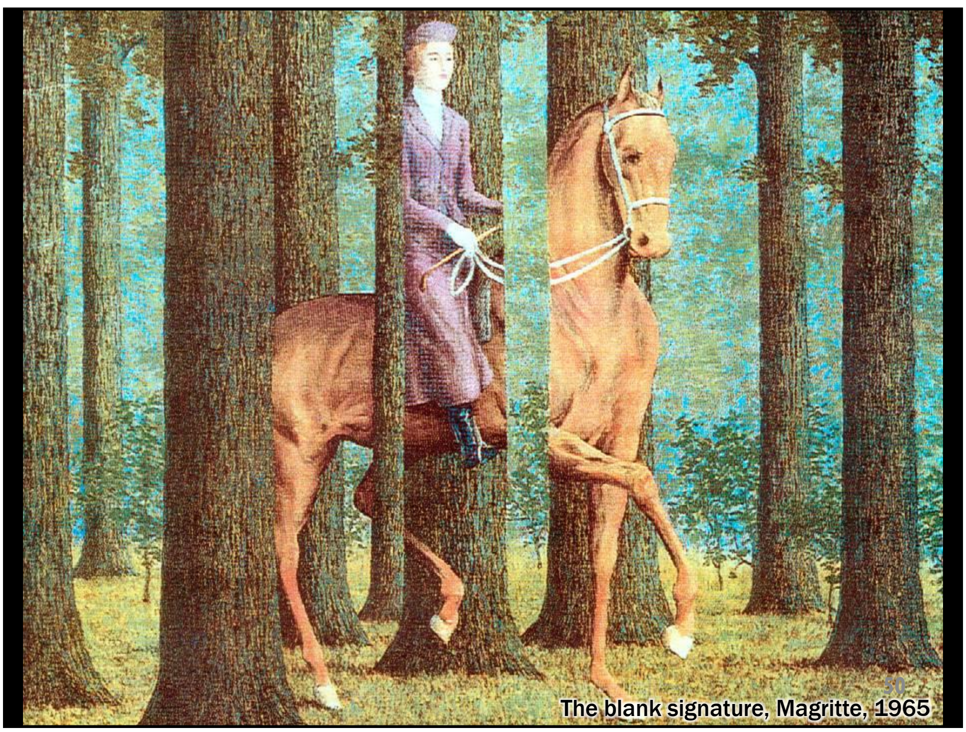

The blank signature, Magritte, 1965

Questions?

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More information about this work

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More information about this work

- Atman, C. J., Hayes, B., Richey, W., Wang, C., & Campbell, R. C. (2013). Designing your personal design process: Report from HCDE directed research group, January to March, 2013 (CELT Technical Report CELT-13-01). Seattle, WA: Center for Engineering Learning & Teaching, University of Washington.
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